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PROCEDURAL GUIDE FOR FEASIBILITY STUDY OF BUILDING PROJECT

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ABSTRACT

1. The construction industry has been a crucial sector in the development of human civilizations throughout history. It encompasses a wide range of activities, including construction of buildings, infrastructure, roads, bridges, and other physical structures. The development of the construction industry has been shaped by various factors, including advancements in technology, changes in materials and building techniques, economic conditions and societal needs. Over time, the construction industry has benefited from technological innovations that have improved efficiency, safety and sustainability. Rapid urbanization and population growth in various regions have led to increased demand for housing, infrastructure and commercial spaces. This has driven the construction industry to expand and adapt to meet these growing needs. Safety and Quality Standards increase emphasis on worker safety and ensuring high-quality construction leading to the implementation of rigorous safety standards and quality control measures. This article is a manual guide on the procedures followed to conduct the feasibility study of building project in compliance to the aforementioned aspects. 2. At this article production, the author utilizes data collected from various literatures including government policies and regulations, building codes, testing manuals, safety and environmental guides and digital transformations, BIM and collaboration with the architects, engineers, contractors and project developers intervening throughout the building project lifecycle. 3. For the building project lifecycle, a

feasibility study was found as a crucial initial step in the planning and development of it. It serves as a comprehensive assessment to determine whether the proposed project is viable, practical and financially feasible before any significant resources are invested. It requires a Serie of studies including architectural study by which a site analysis, program development, concept development, design development and construction documents are done using CAD software like AutoCAD, ArchiCAD etc. The structural study in which the reinforced concrete structural elements like beam, slab, stair, column and footing are analyzed and designed using structural design software like Etabs, protostructure etc. A geotechnical study consisting of soil testing, an environmental and social impact assessment (ESIA) is conducted to assess the negative and positive impacts of the project to the environment, the topographic study was found to be conducted for assessing the site layout and leveling. The MEP and bill of quantity (BoQ) were found to be of importance to conduct for the quality, functioning, performance and overall budget of the building project. 4. As an ongoing process with arising new challenges and opportunities, the construction industry is evolving to meet the changing demands of society, technology, and the environment. To achieve this, requires qualified personnel and compliance with the rules, regulations, guidelines and design standards for quality, safety, cost effectiveness and environmental protection. Engineers, students& researchers, entrepreneurs and project developers in the field of construction were recommended to conduct the feasibility study and comply with the described procedures to sustain quality& stability of building infrastructures.

KEYWORDS: feasibility,[1] architecture,[2] structure analysis,[3] geotechnic,[4] EIA,[5] topography,[6] MEP,[7] procedure,[8] BoQ.[9]

INTRODUCTION

A feasibility study for building construction is a comprehensive analysis conducted to assess the practicality and viability of a construction project. It helps determine whether the proposed building project is financially, technically, and environmentally feasible before investing significant resources into it. Below are the key components to consider when conducting a feasibility study for building construction

1. Project Description: Provide a clear and detailed description of the proposed building project, including its purpose, scope, size, and intended use.

2. Market Analysis: Evaluate the demand for the building and assess market conditions. Analyze factors such as location, target audience, competition, and potential occupancy rates.
3. Site Evaluation: Assess the suitability and accessibility of the proposed construction site. Consider factors like land availability, zoning regulations, environmental impacts, infrastructure, and transportation.
4. Technical Feasibility: Determine whether the project is technically feasible. Evaluate the building design, architectural plans, and engineering requirements. Consider potential challenges and constraints in the construction process.
5. Financial Analysis: Assess the project's financial viability. Estimate the total construction cost, including materials, labor, permits, and other expenses. Compare it to the projected revenue from the building's use over its intended lifespan.
6. Cost-Benefit Analysis: Identify the potential benefits and returns on investment. Analyze the cost-benefit ratio and the payback period for the project.
7. Legal and Regulatory Compliance: Examine local building codes, permits, and legal requirements to ensure the project complies with all relevant regulations and permits.
8. Risk Assessment: Identify potential risks and uncertainties that may affect the project's success. These could include market fluctuations, construction delays, or unforeseen environmental issues.
9. Sustainability and Environmental Impact: Evaluate the environmental impact of the construction project and consider sustainable design practices. Assess any potential long-term benefits of green building initiatives.
10. Stakeholder Analysis: Identify all stakeholders involved in the project and understand their interests, concerns, and expectations.
11. Schedule and Timeline: Develop a realistic construction schedule and timeline for the completion of the project.
12. Exit Strategy: Consider an exit strategy in case the project becomes unfeasible at any stage.

By conducting a thorough feasibility study, you can make informed decisions about whether to proceed with the building construction project or make necessary adjustments to ensure its success. It also helps attract potential investors or secure financing from lenders who may want to see evidence of the project's feasibility before committing funds.

1. Description of Study

Feasibility study consists of a set of studies among which architecture, geotechnic, structure, MEP, topography, EIA, bill of quantities.

2.1. Influence Diagram for feasibility study components

Table 1: Studies conducted in feasibility study of building project.

1. Architecture ***Influences:*** structure, MEP, EIA and Topographic study ***Description*** The architectural design is a comprehensive examination set for the overall vision, special layout, and aesthetic of the building, which impacts the structural requirements, MEP systems, environmental considerations, and site-specific factors and overall functionality.	***1. Structure*** ***Influences:*** MEP, EIA and BoQ and Topographic study ***Description*** The structural design dictates the building's stability, load-bearing capacity, and layout. It affects the placement and integration of MEP systems, determines material quantities for BoQ and is influenced by the site's geotechnical characteristics.
1. MEP (Mechanical, Electrical, Plumbing) Systems ***Influences:*** Architecture, structure and BoQ. ***Description:*** MEP design incorporates heating, cooling, electrical, and plumbing systems. It needs to align with architectural spaces, fit within structural considerations, and be quantified for the Bill of Quantities.	***1. Environmental Impact Assessment (EIA):*** ***Influences:*** Architecture, Topographic Study. **Description:** EIA evaluates the environmental effects of construction It is influenced by architectural choices and considers the impact on the site's topography.
1. Topographic study ***Influences:*** Architecture, EIA. **Description:** A topographic study assesses the site's physical features. It guides architectural decisions and contributes to the environmental impact assessment.	***1. Geotechnical Study*** ***Influences:*** Structure and BoQ. **Description:** Geotechnical analysis examines soil conditions to determine foundation requirements This directly impacts the structural design and influences the material quantities in the Bill of Quantities.
1. Bill of Quantity (BoQ) ***Influences:*** Structure, MEP, Geotechnical Study. **Description:** BoQ lists the materials and quantities required for construction. It's influenced by the structural design, MEP system requirements, and geotechnical study results.	

2.2. Description of Architectural study

The architectural study of a building refers to the process of analyzing and understanding the design, construction, and function of a structure from an architectural perspective. It involves a comprehensive examination of various aspects of the building, including its aesthetics, spatial layout, structural systems, materials, environmental considerations, and overall functionality.

Architectural study is an essential phase in the design and construction process, and it usually starts with the following key steps

1. Site analysis: Understanding the site's location, topography, climate, and surroundings to determine the best orientation and placement of the building for optimal functionality and environmental impact.
2. Program development: Defining the requirements and functions of the building in consultation with the client or users. This step involves understanding the purpose of the building, the intended activities, and the spatial relationships needed.
3. Conceptual design: Exploring various design ideas and conceptualizing the building's form, style, and spatial organization. Architects often use sketches, diagrams, and 3D models to communicate their ideas.
4. Design development: Refining the chosen concept and developing it further into a more detailed and functional design. This phase includes resolving technical and structural challenges, selecting appropriate materials, and considering sustainable design principles.
5. Construction documentation: Creating detailed drawings, specifications, and plans that provide all the necessary information for contractors to build the structure. This includes architectural drawings, structural plans, electrical and plumbing layouts, and other technical documents.
6. Building codes and regulations: Ensuring that the design complies with local building codes and regulations to obtain necessary permits and approvals for construction.
7. Construction administration: Overseeing the construction process to ensure that the building is constructed according to the design intent and specifications. This may involve regular site visits, coordinating with contractors, and addressing any design changes or issues that arise during construction.

Throughout the architectural study, architects consider factors such as aesthetics, functionality, safety, sustainability, accessibility, and the building's relationship with its surrounding environment. They strive to create innovative and well-designed spaces that meet the needs of the users while harmonizing with the context in which the building is located.

2.3. Description of Structural study

Structural study of a building is a comprehensive examination and analysis of its structural components, materials, and systems to ensure that it can safely support its intended loads and functions throughout its lifespan. This study is a crucial aspect of the design and construction process, as it helps identify potential weaknesses, safety issues, and optimization opportunities. It refers to analysis of reinforced concrete and steel behaviors under limit states (ultimate limit states and serviceability limit state).

Key components of a structural study include

1. Load analysis: Understanding the various types of loads that the building will experience, such as dead loads (permanent loads like the weight of the building itself and fixed elements), live loads (temporary loads like occupants, furniture, and equipment), wind loads, seismic loads, and other environmental forces.
2. Structural system evaluation: Determining the most appropriate structural system for the building based on its size, shape, function, and anticipated loads. Common structural systems include frame structures (steel or reinforced concrete), load-bearing masonry, and hybrid systems.
3. Material analysis: Evaluating the properties and characteristics of materials used in the construction, such as concrete, steel, wood, masonry, etc. This analysis ensures that the selected materials can withstand the applied loads and environmental conditions.
4. Structural design calculations: Performing mathematical calculations and simulations to ensure that all structural elements (columns, beams, slabs, foundations, etc.) have sufficient strength and stiffness to support the loads without failure.
5. Seismic analysis: In regions prone to earthquakes, a seismic analysis is conducted to assess the building's ability to withstand seismic forces and to design appropriate earthquake-resistant features.
6. Foundation study: Analyzing the soil conditions and designing suitable foundations that can safely transfer the building loads to the ground.
7. Structural modeling: Using computer-aided design (CAD) and building information modeling (BIM) software to create detailed 3D models that simulate the building's behavior under different loads and conditions.
8. Code compliance: Ensuring that the building design meets all relevant building codes, standards, and regulations to guarantee safety and legal compliance.
9. Retrofitting and strengthening recommendations: If an existing building is being studied, the assessment may include recommendations for retrofitting or strengthening measures to improve its structural integrity and safety.
10. Quality control and inspection: Conducting regular inspections during construction to verify that the building is being constructed according to the approved structural design and ensuring the quality of materials and workmanship.

Overall, a thorough structural study is essential to ensure that the building is safe, stable, and resilient, providing a sound foundation for its intended purpose and lifespan. Professional structural engineers typically carry out these studies to ensure that all technical aspects of the building's structure are carefully considered and implemented.

2.4. Description of Geotechnical study

A geotechnical study, also known as a soil investigation or geotechnical survey, is a critical component of the construction process for any building or infrastructure project. It involves evaluating the site's soil, rock, groundwater, and other geologic conditions to assess their stability and suitability for construction. The purpose of a geotechnical study is to provide valuable information and recommendations to ensure the safety and longevity of the building's foundation and overall stability.

The steps involved in a geotechnical study for building construction:

1. Site Investigation: Geotechnical engineers will conduct a thorough investigation of the site. They will collect soil and rock samples at various depths through drilling, sampling, and testing methods. The samples are then analyzed in a laboratory to determine their properties.
2. Soil Analysis: The soil analysis involves testing the samples to understand their composition, density, strength, permeability, and settlement characteristics. This data helps engineers assess how the soil will behave under different loads and conditions.
3. Groundwater Assessment: The study also assesses the groundwater level and flow conditions at the site. Understanding groundwater conditions is crucial as it can affect the stability of the foundation and may require additional engineering measures such as dewatering.
4. Bearing Capacity Analysis: One of the critical aspects of a geotechnical study is determining the bearing capacity of the soil. The bearing capacity is the ability of the soil to support the loads from the building's foundation without excessive settlement or failure.
5. Settlement Analysis: Geotechnical engineers also evaluate the potential settlement of the building under different loads. Excessive settlement can lead to structural issues, so it is essential to consider this in the design process.

6. Slope Stability Analysis: For buildings on slopes or hilly terrain, slope stability analysis is conducted to assess the risk of landslides or slope failures that could impact the building's safety.
7. Foundation Recommendations: Based on the findings of the geotechnical study, the engineers provide recommendations for the type of foundation best suited to the site conditions. The foundation could be shallow (e.g., spread footings) or deep (e.g., piles) depending on the soil characteristics.
8. Construction Recommendations: Geotechnical engineers may also suggest specific construction techniques and ground improvement methods to enhance the site's stability and prevent potential issues during and after construction.
9. Report and Documentation: All the findings, data, and recommendations are compiled into a geotechnical report. This report serves as a crucial reference for the project's structural engineers, architects, and contractors during the design and construction phases.

Overall, a geotechnical study is a fundamental part of the building construction process that ensures the safety and success of the project by addressing any potential geotechnical challenges and providing appropriate engineering solutions. It is essential to engage experienced geotechnical engineers to conduct a comprehensive study for any building project.

2.5. Description of EIA

An Environmental and Social Impact Assessment (ESIA) is a critical process conducted before commencing a building project. It evaluates the potential environmental and social impacts the project might have and suggests appropriate measures to mitigate these impacts. Below is an outline of the main components typically included in an ESIA for a building project:

1. Introduction and Project Description

- Overview of the building project, its purpose, and location.
- Description of the project's objectives and scope.

1. Legal and Regulatory Framework

- Identification of relevant environmental and social regulations and guidelines that apply to the project.
- Explanation of how the project complies with these regulations.

2. Baseline Environmental and Social Conditions

- Detailed description of the existing environmental and social conditions of the project area.
- Assessment of various environmental factors such as air quality, water resources, soil, flora, fauna, and noise levels.
- Analysis of social aspects, including demographics, cultural heritage, land use, and community dynamics.

3. Identification and Assessment of Potential Impacts

- Prediction and evaluation of potential environmental and social impacts that the building project may generate during construction and operation phases.
- Evaluation of direct and indirect impacts, as well as cumulative effects.

4. Mitigation Measures

- Development of a plan to minimize and manage identified negative impacts.
- Description of mitigation measures for each significant impact.
- Explanation of how these measures will be implemented and monitored.

5. Alternatives Assessment

- Consideration of alternative project designs or locations that might have lower environmental and social impacts.
- Comparison of potential impacts and benefits of each alternative.

6. Public and Stakeholder Engagement

- Description of the consultation process with local communities, stakeholders, and relevant authorities.
- Incorporation of public feedback and concerns into the assessment.

7. Resettlement and Compensation Plan (if applicable)

- If the project involves resettlement or displacement of people, a detailed plan for compensation and rehabilitation should be included.

8. Emergency and Contingency Plans

- Measures to address potential emergencies or accidents that may result in environmental or social harm.

9. Monitoring and Reporting

- Outline of the monitoring activities to assess the effectiveness of mitigation measures and compliance during the project's lifecycle.
- Reporting mechanisms to update stakeholders and regulatory authorities on the project's environmental and social performance.

10. Conclusion and Recommendations

- Summary of the ESIA findings and recommendations for decision-makers regarding the project's feasibility and approval.

It's important to note that specific requirements for an ESIA may vary depending on the country, local regulations, and the scale of the building project. Therefore, it's essential to consult with local environmental and social authorities to ensure compliance with the appropriate guidelines and regulations.

2.6. Topographic Study

A topographic study, also known as a site survey or land survey, is an essential process in the early stages of building development. It involves mapping and analyzing the physical features and characteristics of the land where the building is planned to be constructed. The information obtained from a topographic study is crucial for architects, engineers, and other stakeholders to design the building appropriately and ensure its stability and compatibility with the site.

The key steps involved in a topographic study for building construction

1. Site Inspection: The survey team visits the site and inspects the area to assess its size, shape, boundaries, and any unique features or challenges. They gather information about existing structures, vegetation, bodies of water, utilities, and other relevant aspects.
2. Land Surveying: The surveyors use specialized equipment, such as total stations and GPS devices, to measure the elevation, coordinates, and contours of the land. They create a detailed map, known as a topographic map, representing the terrain's natural and man-made features.
3. Contour Mapping: Contour lines are drawn on the topographic map to represent the land's elevation. Contour lines connect points of equal elevation and help visualize the slopes, hills, valleys, and overall topography of the site.

4. Soil Analysis: Soil samples may be collected at various locations on the site to determine the soil's composition, bearing capacity, and potential for settlement. This information is crucial for foundation design and construction.
5. Drainage Assessment: The surveyors evaluate the site's drainage patterns and identify areas prone to water accumulation or flooding. Proper drainage planning is essential to prevent water-related issues in the future.
6. Utility Mapping: Existing underground utilities, such as water lines, sewer lines, and electrical cables, are located and mapped to avoid interference during construction.
7. Environmental Considerations: The survey team assesses any environmental factors that might impact the building's design or construction, such as protected areas, wildlife habitats, or wetlands.
8. Legal Boundaries: The surveyors verify and mark the legal boundaries of the property to ensure that the building complies with local zoning and building regulations.
9. Geotechnical Investigation: Depending on the site's complexity and potential geotechnical challenges, a more in-depth geotechnical investigation may be necessary. This involves analyzing soil properties and assessing potential risks such as landslides or sinkholes.
10. Report and Recommendations: The survey team compiles all the data collected during the study and provides a comprehensive report with their findings and recommendations. This report serves as a crucial reference for the design and construction teams.

In summary, a topographic study is a crucial initial step in the building development process as it provides vital information about the site's characteristics, allowing architects and engineers to design structures that are safe, efficient, and compatible with the land. It also helps identify any potential challenges or issues that need to be addressed before construction begins.

2.7. Description of MEP

MEP stands for Mechanical, Electrical, and Plumbing. In the context of building construction, MEP refers to the systems and infrastructure that provide essential services to a building to make it functional, safe, and comfortable for its occupants. These systems are critical for the operation and maintenance of any building and are typically installed during the construction phase. The MEP components are described below:

1. Mechanical: The mechanical system in a building involves heating, ventilation, and air conditioning (HVAC). This system is responsible for providing a comfortable and

controlled indoor environment by regulating temperature, humidity, and air quality. It includes equipment such as boilers, chillers, air handlers, fans, and ductwork.

2. Electrical: The electrical system encompasses the electrical distribution, lighting, power outlets, and other electrical components. It provides electricity to all parts of the building, including lighting fixtures, appliances, and other electrical devices.
3. Plumbing: The plumbing system deals with water supply, drainage, and sewage disposal. It ensures a proper supply of clean water for various uses within the building and also handles the efficient removal of wastewater and sewage.

These systems are designed to work together to maintain a safe and comfortable environment within the building while minimizing energy consumption and ensuring the building's sustainability. They require careful planning and coordination during the design and construction phases to ensure proper installation and integration. It's essential to have skilled professionals, such as mechanical engineers, electrical engineers, and plumbing engineers, involved in the design and implementation of MEP systems to ensure they meet local building codes and standards while fulfilling the specific requirements of the building and its occupants.

2.8. Bills of Quantities (BOQ) and Estimates

2.8.1. Bills of Quantities (BoQ)

Bills of Quantities (BOQ) and estimates are essential documents used in construction projects to quantify and cost the materials, labor, and equipment required to complete the building works. Both play a crucial role in the tendering process and help ensure that the project's costs are properly planned and controlled. Here's an overview of each:

The bill of Quantities is a detailed document that itemizes all the materials, labor, equipment, and other elements required to complete a construction project. It is usually prepared by a quantity surveyor based on the project's architectural and engineering drawings, specifications, and project scope. The BOQ is organized into different sections and typically includes the following:

- ✓ **Description of work:** This section outlines the scope and details of each item or element in the project, such as foundations, walls, roofs, finishes, plumbing, electrical works, etc.
- ✓ **Quantities:** The BOQ provides precise measurements or quantities for each item, allowing contractors to accurately price and procure the necessary materials and resources.

- ✓ **Rates:** It includes the rates for each item or activity, which may be based on market rates or rates specified by the client or the construction company. The rates are multiplied by the quantities to determine the total cost of each item.
- ✓ **Provisional Sums and Contingencies:** The BOQ may also include provisional sums and contingencies for unforeseen or uncertain items that may arise during construction.
- ✓ **Summary:** The document usually ends with a summary of the total cost of the project.

The BOQ includes detailed information such as

- Quantities of materials required (e.g., cement, bricks, steel, etc.)
- Labor hours and rates for different construction tasks
- Equipment needed for the project (e.g., cranes, excavators, etc.)
- Provision for contingencies, overheads, and profit margins

The primary purpose of a BOQ is to enable accurate cost estimation, tendering, and cost control during the construction phase. It helps contractors and clients understand the scope of work and the associated costs.

2.8.2. Estimates

The estimate is an approximate calculation of the overall cost of a construction project. It is usually prepared based on preliminary information and assumptions about the project's scope, scale, and complexity. Estimates are essential during the early stages of project planning to determine its feasibility and budgetary constraints.

There are different types of estimates, including:

- **Preliminary Estimate:** Prepared at the initial stages of the project based on limited information to assess overall project feasibility.
- **Detailed Estimate:** Prepared using detailed BOQ and specific project requirements, providing a more accurate cost projection.

Estimates are valuable tools for clients, developers, and contractors to understand the potential cost implications of the project and make informed decisions about its viability and financing.

In summary, a Bill of Quantity provides a detailed breakdown of all the components and quantities required for a construction project, while an estimate gives an overall *approximation of the project's cost. Both documents play crucial roles in planning, budgeting, and executing successful building projects.*

1. RESEARCH DESIGN

The present data of this article were captured from a desk review and consultation of various literatures among which codes of design (BS, Euro codes, RHA, American standards, ASTM, AASHTO and ACI, laws on Environment, WB ESSs, laws and regulations etc.). The analytical, qualitative and analogous methods were used to produce the content guide of this article.

3.1.Procedural Guide For Architectural Study

Generally, Architectural software is used in the process of architectural study. By use of a computer Aided design software namely “ArchiCAD”. Architectural software is evolving rapidly from an “Automator” of two-dimensional drafting to a three-dimensional building simulator. As a result of this evolution, the architect’s ability to construct a “virtual building” on a desktop computer, to simulate the building’s behavior both before it is built and throughout its life cycle.

The ArchiCAD is a software tool for architects working in the architecture-engineering-construction (AEC) industry for designing buildings from the conceptual phase all through to the construction phase. It is a multi-versions software currently ranging from ArchiCAD 2.0(Released in 1986) to ArchiCAD 26.0 with the macOs12.3 Windows10 platform (Released in 2022).

ArchiCAD offers a complete solution and unlike other CAD systems, has been built on the foundation of architecture. The architectural study predicts how the building will look in 10 to 20 years and this affects the way architects design it. ArchiCAD helps us be clear about the separation of systems and get a sense of how the building will perform.

Table2: Procedure guide for Architectural study.

Procedural features	**Working tasks**
Project Initiation and Research	- Identify the purpose and function of the building (residential, commercial, institutional, etc.) - Study the site's context, including topography, climate, surroundings and accessibility.
Concept development	- Generate multiple conceptual ideas - Design approaches based on the project's goals and requirements - Create sketches, diagrams and mood boards to visualize and communicate design concepts - Program planning and space arrangements
Creating the Virtual Building Schematic design	- Establishing the Base Building Layout - Plan air circulation, natural light, ventilation and other designs - Create preliminary floor plans, elevations and sections, spatial layout and key design elements. - Viewing the Building in 3D. - Working with Stories - Completing the Building Envelope
Design development	- Develop schematic detailed design and refined drawings - Specify materials, finishes and building systems - Integrate structural, mechanical, electrical engineers 'inputs into design. - Adding Final Details
Documenting and presentation	- Placing the Building on a Site/layout - Creating Building Schedules - Create comprehensive construction drawings - Develop perspectives and animation - Producing and Publishing Drawings - Present architectural results to client.

3.2.Procedural Guide For Structural Study

The structural design is carried out on reinforced concrete building frame to ensure safety and reliability. The structural design of different members of the building frame are created by use of the physical model. Material properties are assigned to different materials making up the structure and loads (both gravity and lateral: earthquake) are applied. The analysis and design are done for all members of the building.

The primary aim of all structural design is to ensure that the structure will perform satisfactorily during its design life. Specifically, the designer must check that the structure is capable of carrying the loads safely and that it will not deform excessively due to the applied loads. This requires the designer to make realistic estimates of the strengths of the materials composing the structure and the loading to which it may be subject during its design life (Arya, 2009).

3.2.1. Reasons for Conducting Structural Studies on Buildings.

Table3: Reasons for structural study.

Reasons of structural study	Details
Safety	The primary purpose of structural analysis is to ensure the safety of occupants and users of the building. This study analyzes the structural integrity of a building by identify potential weaknesses, vulnerabilities and risks that could lead to collapse or other safety hazards.
Stability	This study determines whether a building can withstand the loads and forces it may encounter during its lifetime, such as dead loads (permanent static loads like the weight of the building itself), live loads (temporary dynamic loads like occupants, furniture, and equipment), wind loads, seismic loads, and other external forces.
Compliance	The buildings must adhere to local building codes and regulations. Structural studies ensure that a building's design and construction meet these requirements, which are established to safeguard public health, safety and welfare.
Design optimization	Through Structural analysis, engineers optimize the design of building components and systems. By studying different configurations, materials and construction methods. engineers can create efficient and cost-effective designs that meet the necessary safety and performance criteria
Renovation & Retrofitting	The Structural studies are often conducted when renovating or retrofitting existing buildings. Engineers assess the current structural condition, identify potential weaknesses, and recommend modifications or enhancements to improve the building's safety and functionality
Resilience	The structural studies contribute to the resilience of buildings against natural disasters, such as earthquakes, hurricanes, and floods. Engineers design buildings to minimize damage and ensure that they can recover quickly after such events.
Predictive maintenance	The regular structural assessments help to predict maintenance needs and potential issues before they become critical. This proactive approach can extend the lifespan of a building and reduce maintenance costs.
Legal and liability considerations	In case of accidents or failures, structural studies can help determine liability by assessing whether proper design, construction, and maintenance practices were respected.

3.2.2. Building Structural Components

The building structural components are crucial elements that provide support, stability, and integrity to a structure. These components are designed to withstand various forces, such as gravity, wind, seismic activity, and the loads imposed by the structure itself.

These structural components are designed and engineered to work together harmoniously to create a safe, stable, and functional building. The choice of materials, design, and construction methods will depend on factors such as the type of structure, location, local building codes, and intended use.

Table4: Structural components details.

Structural components	**Details**
Foundation	Foundations are the base of a building that transfers the weight of the structure to the ground. They distribute the loads from the building to the soil and must be designed to prevent settlement or shifting.
Columns	Columns are vertical structural members that support the load from above and transfer it to the foundation. They come in various shapes and sizes and are often made of materials like steel, concrete, or wood.
Beam	Beams are horizontal or inclined structural members that carry loads perpendicular to their length and transfer them to columns or walls. They help distribute the load and provide support for the floors and roof.
Slab	Slabs are flat, horizontal structural elements that form the floors and roofs of a building. They can be made of concrete, steel, or other materials and distribute loads to the supporting beams and walls.
Stair	These components provide vertical circulation within a building and are designed to support the weight of people and equipment
Wall	Walls provide vertical support and help distribute loads throughout the building. Load-bearing walls carry the weight of the structure, while non-load-bearing walls separate spaces and provide enclosure.
	Retaining walls are used to hold back soil or other materials and prevent erosion. They are commonly used in landscaping and to create level areas on sloping sites
	Bracing elements and shear walls are designed to resist lateral forces, such as wind and seismic loads. They prevent the building from swaying excessively during these events and enhance overall stability
Roof Truss	Roof trusses are triangular structures that support the roof load and transfer it to the exterior walls or columns. They are often made of wood or steel and can span large distances without the need for additional supports
Foundational tie-downs and anchors	In areas prone to earthquakes or high winds, tie-downs and anchors are used to secure a building's foundation to prevent it from shifting or lifting during these events.
Lintels	Lintels are horizontal structural elements placed over openings, such as doors and windows, to support the load above them and distribute it to the surrounding walls
Piers and pilings	Piers and pilings are vertical structural members that extend deep into the ground to provide support for structures in areas with unstable soil or near bodies of water.

3.2.3. Structural Components of Building

This section of the paper focuses on the procedure of structural study (commonly known as analysis and design) of the building components under consideration of British standards of design (BS). The components include:

- ✓ Reinforced concrete Beam
- ✓ Reinforced concrete slab
- ✓ Reinforced concrete stair
- ✓ Reinforced concrete column
- ✓ Reinforced concrete Footing.

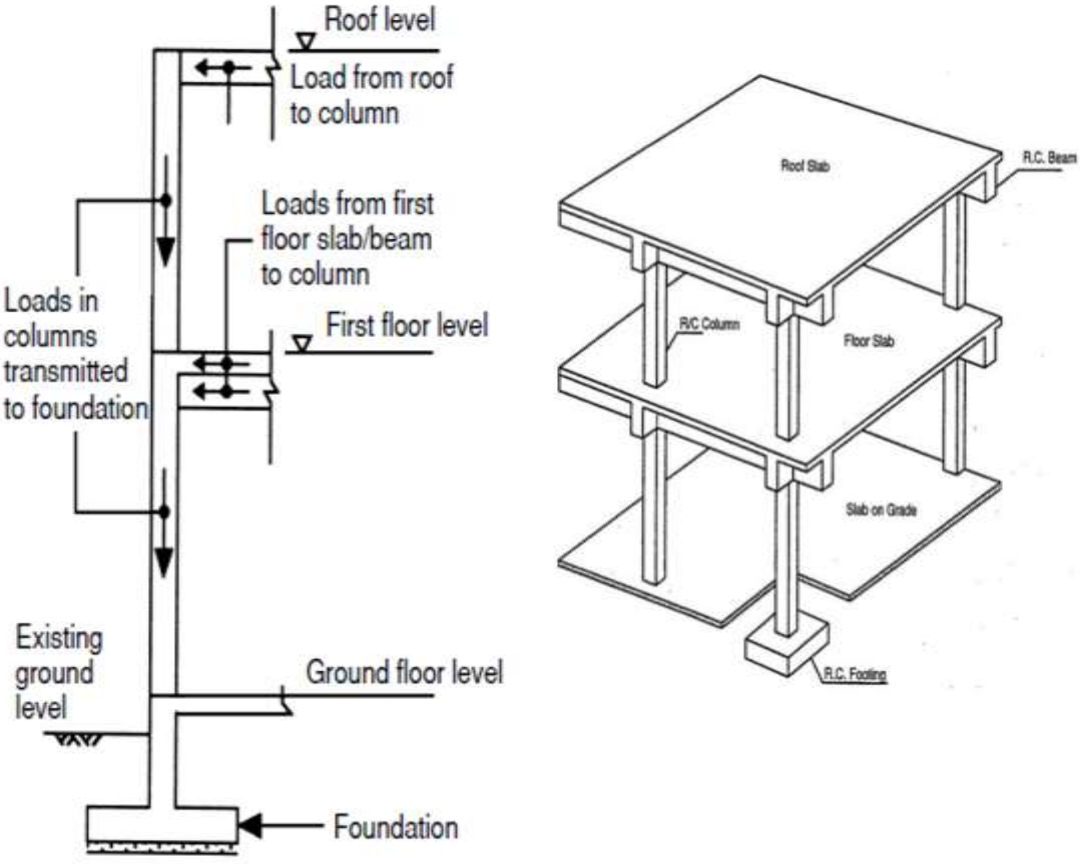


Figure 1: RC Structural components.

3.2.4. Design Considerations

The analysis and design are done through limits states (ultimate limit state, stability limit state and serviceability limit state) under consideration of design standards, guides and regulations.

Table5: Structural design considerations.

Design information	Requirement details	
Building intended use (Classification)	- Residential building - Education &Research building - Health facility building - Commercial building - Warehouse/mercantile building - Industrial building	- Public buildings - Utility buildings - Transport buildings - Sport and entertainment buildings - Defense and security buildings - Agriculture buildings etc.
Design codes and regulations	- BS 8110-1: 1997: The structural use of Concrete. Part 1: Code of practice for design and construction - BS 6399-1: 1996: Loadings for buildings. Part 1: Code of practice for dead and imposed loads. - BS EN 1998-1: Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and rules for buildings. - BS5950-1:2000 Structural use of steelwork in building: Part 1: Code of practice for Design-Rolled and welded section. - BS562-1992: The use of masonry. all part - Manual for the design of reinforced concrete building structures (Institution of Structural Engineers); - Rwanda building Regulations, Edition1, 2009 and Edition2, 2012. - The National Risk Atlas of Rwanda: 2015 etc.	
Structure Design software	- PROSTRUCTURE_ for structure analysis, design, Integration, modeling and documentation. - REVIT Structure_Part of Autodesk Revit suite- for BIM - Tekla structures_ For structural steel detailing and fabrication. - ETABS_ Family of CSI, used for building analysis and design of high-rise structures - STAAD Pro_ From Bentley Systems for structural analysis and design. - SAFE 2016_ From CSI, for design of concrete slabs, foundation systems and mat footings - SAP 2000_Family of CSI, for the analysis and design of complex structures - Advance Design_ From Graitec, for analysis and design of reinforced concrete and steel structures. - RAM Structural system_ From Bentley with integration of various design codes and its focus on concrete and steel building design. - Midas Civil_ For design and analysis of civil structures like bridges, dams and towers. - Robot structural Analysis_ Autodesk's software for advanced structural analysis and simulation, suitable for complex and large-scale structures.	
General loading conditions	- Imposed floor load - Imposed load on stair and ramp - Peak ground acceleration (PGA) - Wind load - snow loads, seismic loads	- Permanent loads/self weight: ✓ Self-weight of Reinforced concrete = 24kN/ m3 ✓ Floor finishes self-weight= 18kN/ m3 ✓ Self-weight of Plaster = 20kN/ m3 ✓ Self-weight of masonry = 20kN/ m3 (burnt bricks)

Exposure conditions	- Fire resistance - Weather conditions	- External conditions - Internal conditions - Nominal cover to all reinforcement (including links)
Sub soil conditions	Allowable soil bearing pressure: subject to soil testing results (better in situ test)	
Structural material data	- Blinding concrete grade: min C15 - Structural Concrete Grade: C25 with fcu=30MPa (Minimum grade) - Yield strength of steel: fy =500 N/ mm^2 (RICA, 2021) - Stirrups and links yield strength: fyv = 500 N/mm2 - Truss members: S235	
Partial safety factors (PSF)	- PSF for Loading@ adverse condition: ✓ Dead Load=1.4 ✓ Live Load =1.6 ✓ Wind Load=1.2	- PSF for materials: ✓ 1.05 for steel, ✓ 1.25 for shear reinforcement, ✓ 1.5 for concrete in actual load, ✓ 1.4 for bond strength and ✓ > 1.5 for bearing strength.
Design parameters	Design Load	- Factored ultimate load considered to design concrete structures from combination of various loads (dead load, live load, wind load…etc). **Design Load= 1.4 DL+1.6LL+1.2WL+1.2…. (Other load occurred)* (BS, 1997)
	Design stress	- Maximum pressure acting on structure due to design load. **For concrete*= $\frac{0.67fcu}{1.5} = 0.45fcu$ and ** For steel*= $\frac{fy}{1.05} = 0.95fy$
	Span length	Distance between two (2) successive supports **Clear span length: in-in distance between 2 successive supports.* **Effective span length: Centre-Centre distance between 2 successive supports*
	Design moment	- Max. ultimate moment due to loadings. It can bend, overturn and fail a structure **Design Moment*= $\frac{WL}{8} = \frac{qL2}{8}$ **W**: point design load, **q**: UDLoad and **L**: span length
	Resisting moment	- Max. resisting capacity of structure itself due to internal properties of the structure. It is subject to material properties, cross-section shape, load distribution, geometry and configuration and connection details. For beams: * $M_{RC} = 0.156 f_{cu} bd^2$ *for a rectangular beam ……………………………….(1)* * $M_{Rc} = 0.45fcu*b*h_f(d-hf/2)$ *for a flanged beam………………………….(2)*
	Shear force	- Internal forces within structure, causing a part of it to slide or deform parallel to its other part. It is in some case same as max. reaction force.
	Shear stress	- *Ultimate design shear stress*: pressure from ultimate shear force. *$v_d = \frac{V}{bd}$…………………………………………………...……...

		(3) - *Resisting shear stress:* max. internal resisting pressure/capacity in structure. $*v_c = \frac{0.79}{\gamma_m}\left(100\frac{A_s}{b_v d}\right)^{\frac{1}{3}}\left(\frac{400}{d}\right)^{\frac{1}{4}}\left(\frac{f_{cu}}{25}\right)^{\frac{1}{3}}$ ……………………………………….*(4)*
	Concrete cover	- *Nominal cover:* Min. thickness of concrete specified in design code/standard to protect reinforcement steel against corrosion in structure. - *Actual cover:* Measured thickness of concrete between outer surface of concrete and steel reinforcement. It considers tolerances, workmanship and deviations.
Note	The Permanent loads (dead loads) depend on structure self weight and its size.	
	The fire resistance requirements are subject to change based on updates to local building codes and regulations	
	The choice of software depends on specific project requirements, type of structure and materials being used and software updated versions.	

3.2.5. Structural Design Procedures

The present section of this paper outlines the design procedures of structural components/elements of building.

3.2.5.1. Reinforced Concrete (RC) BEAM

Table6: RC Beam design procedure.

a. Design procedure of RC rectangular Beam Ultimate design load q=1.4DL+1.6LL+1.2WL [KN/m] **b.** Ultimate Design Moment $M_d=\frac{ql2}{8}$ **c.** Actor $k = \frac{Md}{f_{cu}bd^2} \leq 0.156$ • If k≤0.156, beam is designed as singly reinforced rectangular-only tension reinforcements are applied (Prab Bhatt, 2006); **d.** Level arm $z = d\left[0.5 + \left(0.25 - \frac{k}{0.9}\right)^{1/2}\right]$ **e.** Check if z > 0.95d, if it is greater take z=0.95d **f.** Area of tension steel $A_S = \frac{M}{0.95f_y{*}z}$ • If k>0.156, beam is doubly reinforced rectangular-both tension and compression reinforcements are applied (Prab Bhatt, 2006); **g.** Determine $M_{RC}=0.156*f_{cu}*b*d^2$ Here $Md>M_{RC}$ **h.** Check if $\mathbf{M_{RC} < Md}$ (Ultimate applied moment) If less **i.** Check $d' \ngtr 0.214d \ngtr 0.43x$ **j.** Calculate $A'_S = \frac{M-M_{RC}}{(d-d')(0.95f_y)}$ **k.** $T = C_C + C_S$ $= 0.45f_{cu} * 0.5d * 0.9 * b + 0.95f_y A'_s = 0.2f_{cu} * d * b + 0.95f_y A'_s$	**2.** ***Design procedure of RC flanged beam*** (Prab Bhatt, 2006)**:** **a.** Ultimate design load q=1.4DL+1.6LL+1.2WL [KN/m] **b.** Ultimate Design Moment $M_d=\frac{ql2}{8}$ **c.** Calculate $M_{flange} = 0.45f_{cu}bh_f\left(d - \frac{h_f}{2}\right)$ **d.** $M_{max} = 0.45f_{cu}(b - b_w)h_f\left(d - \frac{h_f}{2}\right) + 0.156f_{cu}b_w d^2$ • If $Md \leq M_{flange}$, then design as a rectangular beam of dimensions b*d. • If $M_{flange} < M \leq M_{max}$, then the required steel area can be determined to satisfy accuracy from formula: $A_s = \frac{M + 0.1f_{cu}b_w d(0.45d - h_f)}{0.95f_y(d - 0.5h_f)}$ • If $M > M_{max}$, then compression steel is required or the section has to be revised. Compression steel is rarely required in the case of flanged beams. But the concrete resists a moment M=M-Max ✓ $A'_s=\frac{M-Mmax}{0.95fy(d-d')}$ compression steel area And the tensile steel area is:

l. Calculate $A_S = \frac{T}{0.95f_y}$

m. Design for shear links (BS8110-1-1997, 2002):

- *Determine design shear stress:* $v_d = \frac{V}{bd}$
- *Determine resisting shear stress that can be resisted by concrete:* $v_c = \frac{0.79}{\gamma_m}\left(100\frac{A_s}{b_v d}\right)^{\frac{1}{3}}\left(\frac{400}{d}\right)^{\frac{1}{4}}\left(\frac{f_{cu}}{25}\right)^{\frac{1}{3}}$
- *Determine shear links required to carry balance:*

Value of v_d [N/mm²]	**Form of shear links to be provided**	**Area of shear links to be provided**
V_d<0.5v_c	*No Shear links*	-
0.5vc<vd <vc+0.4	*minimum link for whole length of beam*	- $A_{sv} \geq \frac{0.4bvSv}{0.95fyv}$ Design shear resistance of 0.4N/mm²
Vc+0.4<vd 0.8$\sqrt{fcu}$ *Or 5N/mm²*	*Links combined with bent up bars*	

n. Check deflection for serviceability limit state.

o. Check the crack for serviceability limit state.

p. Draw the plan and section to show dimensions and reinforcement.

✓ $A_s = \frac{0.2fcubwd + 0.45fcuhf\,(b-bw)}{0.95fy} + A's$

e. Design for shear reinforcement/links (BS8110-1, 2002)

- *Determine design shear stress:* $v_d = \frac{V}{bd}$
- *Determine resisting shear stress that can be resisted by concrete:* $v_c = \frac{0.79}{\gamma_m}\left(100\frac{A_s}{b_v d}\right)^{\frac{1}{3}}\left(\frac{400}{d}\right)^{\frac{1}{4}}\left(\frac{f_{cu}}{25}\right)^{\frac{1}{3}}$
- *Determine shear links required to carry balance:*

[Same as point in m.]

f. Check deflection for serviceability limit state

g. Check the crack for serviceability limit state.

h. Draw the plan and section to show dimensions and reinforcement.

3. *Design procedure of RC continuous beam*: The design of RC Continuous beam follows the values from table below

	@Outer support	*Near middle of end span*	*@1st Interior support*	*@middle of interior span*	*@interior support*
Moment	0	0.09FL	-0.11FL	0.07FL	-0.08FL
Shear	0.45F	-	0.6F	-	0.55F

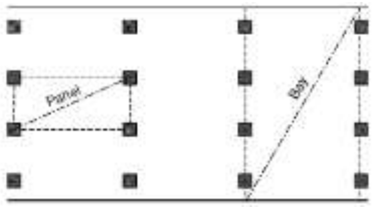
With:

L: effective span

F: total ultimate design load=1.4DL+1.6LL+1.2WL.

3.2.5.2. Reinforced Concrete (RC) SLAB.

A slab is a structural element of building made in panels and bays supported in one or two directions of beams. RC Slabs are commonly used in construction for creating horizontal surfaces including the floors, ceilings and roofs. The slabs provide structural support, distribute loads and resist against bending, shear and other forces. Slab helps to transfer the various floor loads to the beam, then through columns, last to foundation of structure.



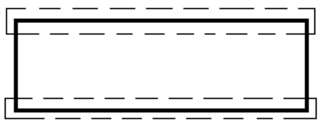
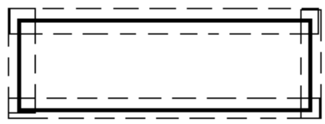
RC Slab is designed to handle various loads like dead loads (weight of slab itself), live loads (weight of people, furniture and other temporary loads) and other imposed loads like wind or seismic forces. The steel reinforcement within the slab provides tensile strength, which helps counteract the weakness of concrete in tension. This combination of concrete's compressive strength and steel's tensile strength makes RC slabs sturdy and durable.

Slab panel: is a slab portion supported with four (4) beams with adjacent continuous edge.

Slab bay: is a slab portion supported with discontinuous edge.

The RCC slab may be simply supported or continuous over one or more supports and may be classified according to the supporting conditions.

Table7: Classification of slabs.

Classification of slabs	
One-way slab	**Two- way slab**
- Slab supported in one direction - Ratio: $\frac{Ly}{Lx} \geq 2$  ----: *Beam support* - —: *Slab*	- Slab supported in 2 directions - Ration: $\frac{Ly}{Lx} < 2$  ----: *Beam support* - —: *Slab*

3.2.5.2.1. Steps involved in design of Slab

The slab is designed following the three (3) main methods including: 1. Moment coefficient methos, 2. Elastic analysis method and 3. Yield line method. A typical exemplar procedure for design a one-way slab by Moment coefficient method.

Table8: Procedures of RC slab design.

The structural designer, during the RCC Slab design, shall follow the steps below:

- **Check the type of slab** (one-way: $\frac{Ly}{Lx} \geq 2$ and two- way: Ratio:$\frac{Ly}{Lx} < 2$);
- **Design the slab panel** with greatest dimensions in both directions by using slab width of 1m.
- **Calculation of slab thickness** (h): $\frac{Lx}{40} \leq h \leq \frac{Lx}{30}$ with d (effective depth) = h-cover-$\frac{\emptyset}{2}$
- **Preliminary dimensioning**
- **Load calculation** (design load=1.4Gk+1.6Qk+1.2Wk, Design Moment);
- **Determine the moment** (BS8110-1-1997, 2002):

✓ Positive moment@ span in short direction: $M^{+}_{sx}=\alpha_{sx}*N*L^{2}_{x}$………*(5).*

✓ Positive moment@ span in long direction: $M^{+}_{sy}=\alpha_{sy}*N*L^{2}_{x}$……….*(6).*

✓ Negative moment @ support in short direction: $M^{-}_{sx}=\beta_{sx}*N*L^{2}_{x}$………*(7).*

✓ Negative moment @ support in long direction: $M^{-}_{sx}=\beta_{sy}*N*L^{2}_{x}$……….*(8).*

Note:

1. α_{sx}, α_{sy}, are positive bending moment coefficients for both short and long directions @span (BS8110-1-P43, 2002);
2. β_{sx} and β_{sy} are negative bending moment coefficients for both short and long directions @support (BS8110-1-P43, 2002);

- **Design for Reinforcement Calculation.**

✓ K=$\frac{Mmax}{fcubd2}$, M_{max} is taken greatest moment between 2 negatives for short and long directions and greatest moment between 2 positives for short and long directions.

✓ For K≤0.156, slab shall be designed for only tension reinforcement and K>0.156, slab shall be designed for both tension and compression. (look@ beam design procedure).

- **Check for shear stress** (BS8110-1, 2002)……. *Require the calculation of shear forces(V) in both directions:*

✓ $v_{sx} = \beta_{vx}*N*Lx$…………………………………….*(9)*

✓ $v_{sy} = \beta_{vy}*N*Lx$…………………………………….*(10)*

✓ Each shear force is considered in each direction (x-direction/short and y-direction_Long)

- **Check for deflection---To comply the "deemed to satisfy condition).**

✓ *Deflection* is the curvature that occurs in a flat, horizontal slab or plate when subjected to loads or forces.

✓ The slab deflection results in downward sagging or bending, leading to a concave shape. It depends on factors like type of material used, thickness and geometry of the slab, the magnitude and distribution of the loads and the support conditions at the edges and underneath the slab. It is determined to maintain it in acceptable limits to maintain structural integrity for the comfort of the occupants.

✓ The deflection check is done as per BS8110-2-Clause 3.1.1, BS8110-1 Clause 3.4.6.3. table 4.1 and table 3.9.

- **Draw the plan and section to show dimensions and reinforcement.**

Design Procedure of RC Continuous One-Way Slab

The design of RC Continuous slab follows the values from table below:

Loading	*@Outer support*	*Near middle of end span*	*@1st Interior*	*@middle of interior*	*@interior support*

			support	*span*	
Moment	0 (-0.04FL*)	0.086FL (0.075FL*)	-0.086FL	0.063FL	-0.063FL
Shear	0.4F (0.46F*)	-	0.6F	-	0.5F

F: Total ultimate design load and **L**: Span length and *****: refer to the case where end supports are fixed.

Note: The design of RCC Slab is currently easily done by use of *structural design software-ETABS, PROTASTRUCTURE. etc.* (Check table 3.2.4 above).

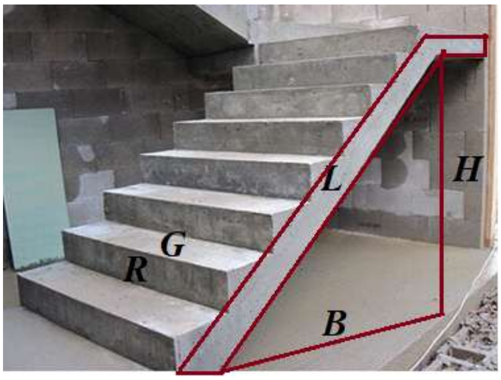
3.2.5.3. Reinforced Concrete (RC) STAIR

3.2.5.3.1. Overview

- In multi-storey buildings, ramps, elevators, escalators and stairs are often used to facilitate vertical circulation of people and goods between interior spaces of buildings. Stairs, when used, provide access to different levels in a building where access height exceeds 600mm. Stairways are sloping one-way spanning slab. Stair is a set of steps (going G+ riser R) leading from one building floor to another floor in of outside the building.
- By shape, RCC Stairs may be straight, circular, helical, spiral or a combination.
- The staircase design focuses on the following components

Table9: RC Stair components.

Staircase components	**Explanatory notes**
Flight	Serie of steps extending from floor to floor through an intermediate landing.
Guard	Protective vertical barrier along edges of stairways, balconies and floor openings
Landing/platforms	Levels used when turns are necessary and break up long climb.
Step	Combination of riser and a nearby tread above
Rise	Distance from floor to floor
Run	Total length of stairs in horizontal plan including landings
Riser	Vertical face of step with height generally taken as vertical distances between treads
Tread	Horizontal face of step with width taken as horizontal distance between risers
Nosing	Projection of tread beyond the riser below
Soffit	Underside of a stair
Railing	Framework supporting handrail &serving as safety barrier
Baluster	Vertical member supporting handrail in a railing
Balustrade	Railing of balusters capped by handrail
Handrail	Protective bar above the stairs for handhold



3.2.5.3.2. RC Stair Design Considerations

Refer to the stair picture in right corner, ***R*** stands for Riser, ***G*** for Going, ***H*** for rise of stair Or height of flight, ***L*** for length of flight and ***B*** stands for horizontal distance between two (2) landings.

- ✓ L=$\sqrt{H^2+B^2}$
- ✓ 3≤ Nos of steps≤12
- ✓ 700mm≥G+2R≥550mm (BS6399-1, 2002) and 63.5cm≥G+2R≥60cm (US, 2002);
- ✓ Thickness of waist: t=$\frac{L}{20}$ for SS Stair slab and t=$\frac{L}{25}$ for Continuous stair slab.

3.2.5.3.2. Stair dimensions based on the category of occupancy and Design Procedures

Table10: RC Stair dimensions and design procedures.

Stair Components	***Residential building***	***Public building***
Landing width	≥b of stair	≥ b of stair
Stair width	0.8-1m	1.8-2.0m
Tread	220-250mm	250-300mm
Riser	150-180mm	120-150mm
Pitch	≤38^0	-
Other considerations		
- BS8110-1-Clause 3.10.2.2		
- Continuous stair slab is designed by Moment=$\frac{WL}{10}$ - W: Total ultimate design load & L: effective span length		

RC Stair Design Procedures

1. Calculate slope/length of flight (L)=$\sqrt{H^2+B^2}$;
2. Calculate loadings (DL, LL, WL), design loads and Moment;
3. Calculate the K_ factor=$\frac{Moment}{fcubd2}$;
4. Calculate lever arm Z=d (0.5+$\sqrt{0.25-\frac{K}{0.9}}$)
5. Calculate the steel area (As) required=$\frac{Md}{0.95fyZ}$
6. Design for shear (as per beam design procedure& conditions)
7. Check for deflection (BS8110-2, 2002)
8. Check the crack as per British standards code provisions.

For crack control, clear distance ≤3d or 210mm (BS8110-1, Crack checking and control, 2002)

9. Draw the plan and section to show dimensions and reinforcement.

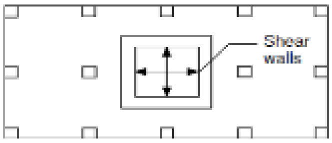
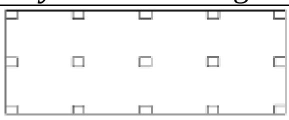
3.2.5.4. Reinforced Concrete (RC) Column

The reinforced concrete column is a structural member designed to carry compressive loads, composed of concrete with an embedded steel frame to provide reinforcement. Columns are carrying roof and floor loads to the foundations.

For design purposes, columns may be classified as short or slender, braced or unbraced, depending on various dimensional and structural factors. *The present study of this article will be restricted to the design of the most common type of column found in building structures, namely short-braced columns* (Prab Bhatt, 2006).

3.2.5.4.1. RC Columns types details

Table11: *Types of RC Columns.*

Braced and Unbraced Columns (BS8110-3, 2002)		**Short and Slender Columns**	
Braced Column	*Unbraced Column*	*Short column*	*Slender/Long column*
if the lateral loads, due to wind are resisted by shear walls.	if the lateral loads are resisted by the sway action of the column.	*For $\frac{Lex}{h}$ and $\frac{Ley}{h}$: < 15 for braced column < 10 for unbraced $*\frac{Le}{b} \leq 12$	*For $\frac{Lex}{h}$ and $\frac{Ley}{h}$: > 15 for braced column > 10 for unbraced $*\frac{Le}{b} > 12$
Le: effective length ***b:*** width of column cross section ***d:*** depth of column cross section ***lex:*** effective height with respect to major axis and ***Ley:*** effective height with respect to minor axis.			
 *Braced in both directions*	 *Unbraced in both direction*	 *short column*	 *slender column*

3.2.5.4.2. RC Column Design considerations

The design of RC Column, the engineer shall consider the following provisions:

- ✓ Short columns are failing when reach their ultimate capacity under applied loads and moment.
- ✓ Slender columns are square, rectangular, circle and polygonal sections used in special cases and deflected due to additional moments caused by deflection and loading.
- ✓ Minimum size of a column must meet fire resistance period of 1.5hours with concrete cover of 250mm size.
- ✓ Effective height of column ***Le=βLo***
- ✓ For slender column ***Lo≤60*minimum thickness of column*;**
- ✓ For unbraced column, if one end is unrestrained: ***Lo≤60Lo or Lo≤*** $\frac{100b2}{h}$

- ✓ Minimum % of reinforcement for both $fy=250N/mm^2$ and $fy=460N/mm^2$ (BS8110-1, Section 3.12 and Table 2.25, 1997) $\frac{100Asc}{Acc}=0.4$
- ✓ Maximum area should not exceed 6% of cross section area of vertical cast column except at laps where 10% is allowed. For horizontal cast column, maximum area is 8%.
- ✓ The diameter of links ≥6mm of $\frac{1}{4}$ dia. of big bar and Maximum spacing=12*dia. minor bars.
- ✓ No steel reinforcement bars to be further 150mm from restrained bar.
- ✓ Laps in columns are located above the base and floor level;
- ✓ Minimum Nos=4bars for rectangular column and maximum Nos =6bars for circular column.

3.2.5.4.3. RC Column (Short column) Design Procedures

For the design purposes, BS 8110 divides the short-braced columns into following three (3) categories:

1. Columns resisting axial loads only (*short braced axially loaded column);*
2. Short braced axially loaded column and bending about one axis symmetrically
3. Columns resisting axial loads and uniaxial or biaxial bending.

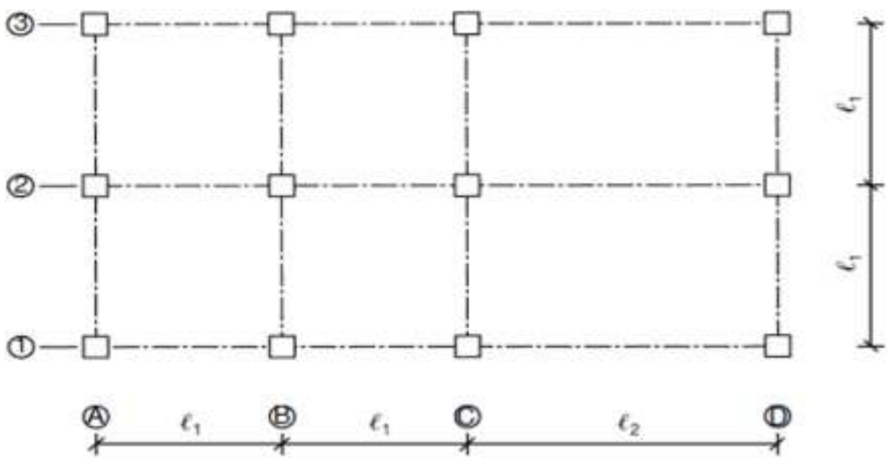


Figure 2: Typical Floor plan.

- Referring to the floor plan shown in *Figure2*, it can be seen that column B2 supports beams which are equal in length and symmetrically arranged. Provided the floor is uniformly loaded, column B2 will resist an axial load only and is an example of category 1.

- Column C2 supports a symmetrical arrangement of beams but which are unequal in length. Column C2 will, therefore, resist an axial load and moment. However, provided that (a) the loadings on the beams are uniformly distributed, and (b) the beam spans do not differ by more than 15% of the longer, the moment will be small. As such, column C2 belongs to category 2 and it can safely be designed by considering the axial load only but using slightly reduced values of the design stresses in the concrete and steel reinforcement.
- Columns belong to category 3 if conditions (a) and (b) are not satisfied. The moment here becomes significant and the column may be required to resist an axial load and uni-axial bending, *e.g. columns A2, B1, B3, C1, C3 and D2*, or an axial loads and biaxial bending, *e.g. A1, A3, D1 and D3*. The design procedures associated with each of these categories are discussed in the subsection below.

Category 1: Short braced axially loaded column (BS8110, 2002)

Example: Column B2 of typical floor plan.

A column having a net cross-sectional area of concrete *A*c and a total area of longitudinal reinforcement *A*sc, the design stresses for concrete and steel in compression are:

*Concrete design stress = 0 67 *f*cu / 1 5 = 0.45*f*cu……………………………………………………*(11)*
* Reinforcement design stress = *F*y / 1.15 = 0.87*fy*……………………………………………….*(12)*

Both the concrete and reinforcement assist in carrying the load.

Thus, the ultimate load *N* which can be supported by the column is the sum of the loads carried by the concrete (*F*c) and the reinforcement (*F*s) with:

*$N = Fc + Fs$
*Fc = stress × area = $0.45 fcu Ac$
*Fs = stress × area = $0.87 fy Asc$
Hence, $N = 0.45 fcu Ac + 0.87 fy Asc$ *(load perfectly applied axially)*
Practically, perfect conditions never exist: so, BS8110, recommend $N = 0.4 fcu Ac + 0.8 fy Asc$…………*(13).*

***Category 2:* Short braced axially loaded column and bending about one_axis symmetrically** (BS8110, 2002)

Example: Column C2 of typical floor plan.

For a column subjected to an axial load and 'small' moment, the latter is taken into account simply by decreasing the design stresses in category 1 by 10%, giving the following expression for the load carrying capacity of the column:

$N = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$ can be used to design columns supporting an approximately symmetrical arrangement of beams provided (a) the loadings on the beams are uniformly distributed, and (b) the beam spans do not differ by more than 15% of the longer.

***Category 3:* Short column subjected to axial load and uniaxial or biaxial bending Moment** (BS8110, 2002)

Example: if conditions (a) and (b) above are not satisfied.

The area of longitudinal steel for columns resisting axial loads and uniaxial or biaxial bending is normally calculated using the design charts. These charts are available for columns having a rectangular cross-section and a symmetrical arrangement of reinforcement (BS8110-3-1985, 2002).

Note: The structural engineer/designer shall keep these in mind

1. BSI issued these charts when the preferred grade of reinforcement was 460N/mm^2. The recommended grade of reinforcement in Rwanda is currently 500N/mm^2 (RICA, Rwanda, 2022). Nevertheless, these charts could still be used to estimate the area of steel reinforcement required in columns but the steel areas obtained will be approximately 10% greater than required. *Figure2* presents a modified version of chart 27 which takes account of the new grade of steel reinforcement.
2. Design charts are available for concrete grades 25,30, 35, 40, 45 and 50 and reinforcement grade 460 in general and 500 particularly for Rwanda.
3. For a specified concrete and steel strength there is a series of charts for different *d/h* ratios in the range 0.75 to 0.95 in 0.05 increments.
4. It should be noted that each chart is particular for a selected value of:

- Characteristic strength of concrete, f_{cu};
- Characteristic strength of reinforcement, f_y;
- *d*/*h* ratio;
- *Value of* $\frac{M}{bh2}$ *(N/mm^2) at X-axis*
- *Value of* $\frac{N}{bh}$ *(N/mm^2) at Y-axis*

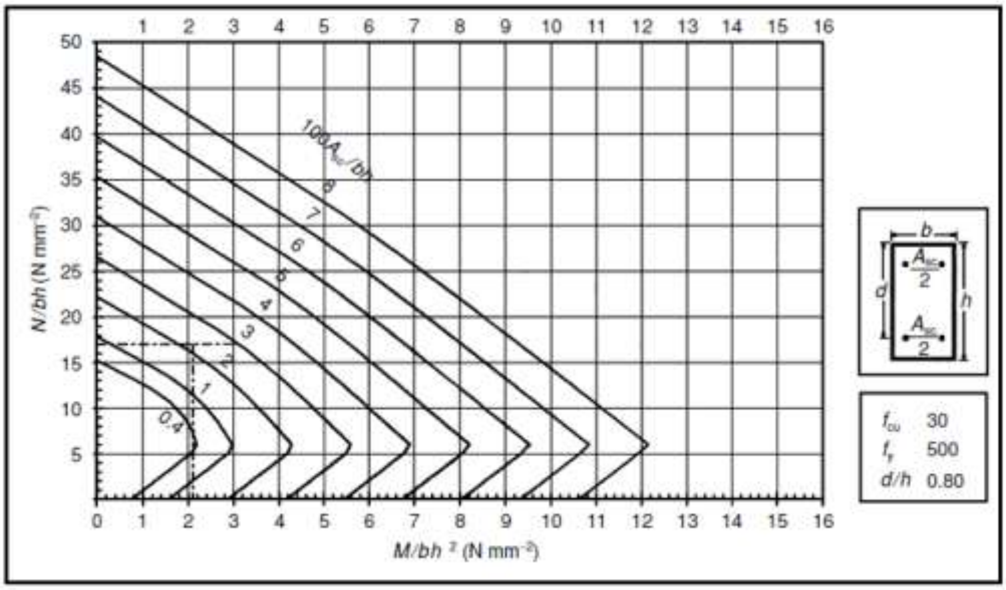


Figure 3: **Typical column design chart for fcu=30, fy=500 and d/h=0.80.**

BRIEF RC COLUMN DESIGN PROCEDURE

1. Identify the column category (1,2 or 3);
2. For category 1 &2, apply the formulas mentioned;
3. For category 3; Determine the ultimate design load (N) and Moment (M);
4. Master the column cross sectional dimensions b, d and h;
5. Select the grade of concrete fcu and fy;
6. Calculate the values $\frac{d}{h}$, $\frac{M}{bh2}$ and $\frac{N}{bh}$;
7. Select the column chart from BS8110-3 Chart No.21 up to 50 considering values $\frac{d}{h}$,fcu and fy;
8. From the chart, select the percentage of steel area from the point ($\frac{M}{bh2}$, $\frac{N}{bh}$);
9. Calculate Asc and Nos of steel reinforcement from the % of Asc and table 3.12 of BS. With $Asc_{required} = \frac{bh}{100}$.
10. Draw the plan and section to show dimensions and reinforcement.

3.2.5.5. Reinforced Concrete (RC) Foundation

The Foundations transfer loads from the building or individual columns to the soil. Since, the soil bearing capacity is much lower than the concrete columns; the loads need to be transferred safely to the soil by using larger areas usually called *shallow foundations*. If the soil has low bearing capacity and the applied loads are very large, the loads are transferred to a deeper soil by use of piles or caissons usually called *deep foundations*.

"Foundation design requires both soil investigation, to determine the most suitable type of foundation and a structural design, to establish the depth and reinforcement of the foundation.

Geotechnical engineers carry out the soil investigation and a structural engineers establish the size and amount of reinforcement for the foundation system" (RP_IPRC, 2022).

3.2.5.5.1. Types of foundations

The type of foundation depends on the soil properties & conditions (BS8004:1986, 2002), type of structure & loading and permissible amount of differential settlement. The foundations are mainly classified into:

Table 12: Types of foundations.

Shallow foundations	**Deep foundation**
- Isolated(pad) bases for individual column (square or rectangular) - combined bases(strip) for several columns - rafts (Mat) for whole building with basements	- isolated pile caps: - raft on piles:

All the above types of foundations may bear directly on the ground or be supported on piles. Only isolated bases are considered in this article.

3.2.5.5.2. Design considerations for isolated base

Isolated pad bases are square or rectangular slabs provided under individual columns. They spread the concentrated column loads safely to the ground and may be axially or eccentrically loaded.

To calculate the area of footing, loads at serviceability limit state are used;

- ✓ Dead plus imposed load: 1Gk+1Qk
- ✓ Dead plus wind load: 1Gk+1Wk
- ✓ Dead plus imposed plus wind load: 1Gk+0.8Qk+0.8Wk.

The bearing pressure under the base of foundation *shall not exceed* the allowable bearing pressure of the soil.

Table13: Typical allowable bearing capacity.

Typical allowable (safe) bearing pressure---subject to change based on soil category				
Soil Category	**Typical bearing value (kN/m^2)**		**Soil Category**	**Typical bearing value (kN/m^2)**
Massive igneous bedrock	10,000		Loose fine sand	<100
Sandstone	2000-4000		Hardy clay	300-600
Shales and mudstone	600-2000		Medium clay	100-300
Gravel, sand and gravel, compact	600		Soft clay	<75
Medium dense sand	100-300			

Assume linear distribution of soil pressure across the base of the footing;

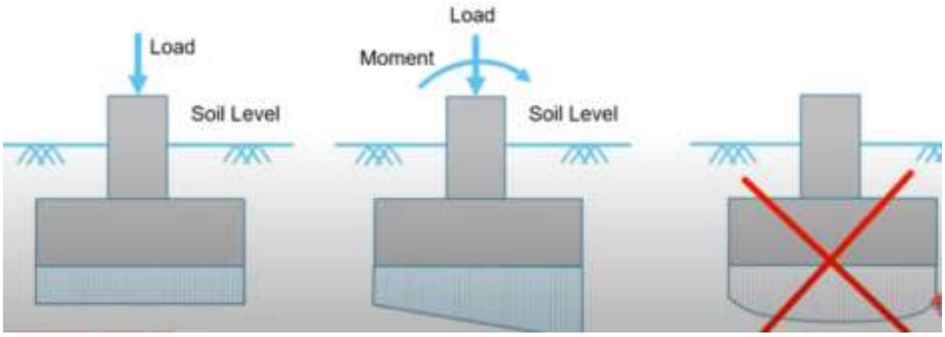


Figure 4: Linear distribution of soil pressure.

- A large concrete cover, shall be used (severe or aggressive exposure)
- ✓ Cover ≥75mm without blinding concrete
- ✓ Cover ≥50mm with blinding concrete.
- Use a concrete grade of at least 35N/mm^2(fcu≥35 MPa)

3.2.5.5.3. RC Concrete footing (Pad) design procedures

BRIEF RC PAD FOOTING DESIGN PROCEDURE

1. Assume a suitable value for thickness(H) and effective depth (d). A guide assumes a shear stress of 0.5vu N/mm^2, so d=$\frac{Nu}{column\ perimeter*0.5vu}$ and H=d+ cover+ ϕ, ***Note:*** (Hmin=300mm) and Nu=ultimate design load.
2. Calculate the plan size of bae (B&D) using allowable bearing pressure and critical loading arrangement (Ns only or Ns &Ms) at serviceability limit state (not ultimate); Base area=$\frac{Gk+Qk+W}{Pb} = B * D$ m^2, with B&D: base length and width.
3. Calculate the bearing pressures associated with critical loading arrangement at the ultimate limit state;
4. Determine the reinforcement required to resist the bending in two(2) directions;
5. Check the direct shear stress at critical sections (at 1d from the face of column);
6. Check the punching shear (at 1.5d from the face of the column);
7. Draw a plan and a section to show dimensions and reinforcements;

Author's key note

1. The structural study is conducted to ensure that the structure will perform satisfactorily during its design life.
2. It refers to analysis and design of all structural elements (concrete, timber and steel structures)
3. In this article, the author has elaborated the manual procedures of concrete structural design to guide the beginners.
4. The author reminds that nowadays, the designers use structural design software (etabs & Safe, protostructure, Midas, etc)

5. For the production of this manual guide, Author has considered the British standard (BS) and other sources.

3.3.Procedural Guide For Geotechnical Study

In situ tests	
Test name	**Purpose**
Dynamic cone penetrometer (DCP)	The test shall be performed at different locations of the site to assess the variation of soil bearing capacity with depth. The soil bearing capacity considered for structure design shall be the average of the bearing capacities from different location.
Trial pit test	Trial pits test excavation shall be done on site in order to get visual information about subsurface including but not limited to soil layers, buried debris if any, size distribution, etc. Also, samples (both disturbed and undisturbed) of soil will be collected from tests pit for laboratory testing. It is better to select the in-situ results for the structural design considerations.
Laboratory tests	
Sieve Analysis	Sieve analysis shall be done on soil to assess the particle size distribution or grading in order to classify the foundation soils. It determines whether the soil consists of predominantly gravel, sand silt or clay sizes (Laboratory, 2000).
Atterberg Limits	Atterberg limits (liquid limit, plastic limit and plasticity index) shall be determined on soil sample to assess the soil state as solid, semi-solid, plastic or liquid in order to assess how it behaves as water content changes. The results will also help in classifying the foundation soils.
Direct Shear test	The test shall be done in order to assess the strength parameters (cohesion and friction angle) of the soil. The parameters shall help in the design of foundations and structures such as retaining walls and stability of slopes.
Consolidation	Consolidation Test shall be conducted in order to determine the rate and magnitude of settlement in soils when soil is restrained laterally and loaded axially. The results of consolidation will be helpful in the design of foundations against settlement.
The detailed list and purpose of the tests are found in the BS1377-2-1990	

Ancient Greek civilization used isolated pad footings and strip-and-raft foundations for building structures. Many of these structures were constructed on silt and soft clay layers. In some cases, the foundation pressure exceeded the load-bearing capacity of the soil and thereby caused extensive structural damage. One of the most famous examples of problems related to soil-bearing capacity in the construction of structures prior to the 18th century is the Leaning Tower of Pisa in Italy (DAS, 2006).

After encountering several foundation-related problems during construction over centuries past, engineers and scientists began to address the properties and behaviors of soils in a more methodical manner, conducting the geotechnical studies. The stability of the foundation of a building depends on the strength and compressibility of the subsoil. Field and laboratory investigations are thus required to obtain information about the subsoil.

For a building construction project, a number of soil tests (both in-situ and laboratory) shall be conducted to acquire knowledge of the foundation soil. The soil testing standards like British Standards (BS) and the America Society for Testing and Materials (ASTM) shall be consulted. The results shall be interpreted in line with the standards provisions and the project in place to decide on whether to improve the concerned soil, which materials to use in construction…etc.

The number of tests that shall be conducted for a mega project of building construction are:

Table 14: *Possible list of geotechnical tests in Feasibility study.*

Author's key note

1. The procedure for each test and equipment used are summarized in Laboratory testing manuals/protocols.
2. The Author recommends between the lab test results and the-in situ test results, to consider and use the in-situ results than lab results in designer's structural considerations as the in-situ results are from the undisturbed samples.

3.4. Procedural Guide For Environmental &Social Impact Assessment (Esia)

For the purpose of environmental protection and social safeguards, the ESIA shall be conducted for a new project of building construction. The ESIA is one of the study components, conducted by the environmental certified expert, certified by the authorized professional certifying body, e.g: The certifying body in Rwanda is "Rwanda Association of Professional Environmental Practitioners (RAPEP)". In any country, the environmental and social Impact Assessment report produced by expert, is evaluated and approved by authorized organ in charge of environment or ecosystem which finally issue the ESIA certificate.

3.4.1. ESIA versus ESA

Table 15: Difference between ESIA and ESA.

ESIA	ESA
- ESIA: environmental and social Impact Assessment - Conducted for a *NEW* project to start; - Conducted by team of certified environmentalist (Expert); - Certified by Rwanda Development Board (RDB); - A mandatory for feasibility study in project.	- ESA: Environmental and social Audit; - Conducted for an existing project to resume,…. - Conducted by team of certified environmentalist (Expert); - Certified by Rwanda Environmental Management Authority (REMA)

3.4.2. Purpose of ESIA and ESA

Respectively the ESIA and ESA are conducted

- To assess the significant environmental and social benefits the project brings,
- To assess substantial positive and negative impacts on communities and the natural environment
- Propose the mitigation measures for the negative impacts.

3.4.3. Considerations and consultation

To conduct the ESIA and/or ESA, the environmentalist shall consider the laws, rules, regulations, guidelines and protocols in place regarding the environment and the projects in study.

Case study: Rwanda, In Rwanda, the baseline

- The ministerial order **№ 001/2019 of 15/04/2019** establishing the list of Projects that must undergo Environmental impact assessment (EIA), Instructions, requirements and Procedures to conduct Environmental impact assessment (which is defined as systematic process of identifying environmental, social and economic impacts of a project) before a decision of its acceptance is made, mainly in its article 3 and 4.

- Under this order, all buildings classified as residential, commercial, administrative or institutional sports facilities, social, cultural, and assembly and religious buildings, hotels, health facilities, educational buildings, or other publicly accessible facilities fulfilling at least two of the following conditions:

i. having capacity to host more than five hundred (500) people;

ii. having a total floor area exceeding one thousand and five hundred square meters (1500 sqm);

iii. Built in plot size exceeding one thousand square meters (1000 sqm).

- The Law N° 48/2018 of 13/08/2018 related on National Environmental Management;
- General Guidelines and Procedures for Environmental and social Impact Assessment (ESIA), 2007
- Other laws &protocols regulating the way-why-when-how to conduct the ESIA;
- Consulting people in and neighboring the project site.

3.4.4. The procedure for ESIA

The ESIA and ESA are conducted following the steps below:

- Identify and understand the project by environmental expert;
- Visit the project site and consult the project affected people (PAP) by environmental expert;
- Prepare the project brief and submit to Authorizing Body (e.g: RDB for ESIA or REMA for ESA, in Rwanda);
- Authorizing body to visit the project site to understand the project;
- Preparation of terms of references (ToRs) and communicate it to the project developer and environmentalist;
- Preparation and submission of the ESIA or ESA report to the authorizing body by environmental expert;
- The signature of conditions for approval by both project developer and authorizing body;
- Issuance of ESIA or ESA certificate to project developer by authorizing body.

3.4.5. ESIA and ESA Report structure *(subject to change,….)*

The ESIA and ESA report may contain but not limited to:

✓ **Executive Summary**
✓ Name and location of the project
✓ Name of the project developer
✓ Name of expert preparing the report
✓ Main findings identified
✓ A Summary of the ESIA process including any obstacles encountered and Mitigation measures
✓ Prioritized recommendations in environmental monitoring plan.

✓ **Introduction**

The introduction section will include the following:

- Author presentation include the auditor's representatives who participated in the audit and the name and responsibilities of each audit team member;
- Developer presentation - Objective, scope and plan of the study
- Methodology used for conducting the ESIA

✓ **Legislative and Regulatory Considerations**: Laws, regulations, policies and orders regarding environmental protection and safeguards.

✓ **Baseline data**

- The expert will provide summary of information on the status of the study area, location, data related to the demography, project…. etc.

✓ **Project description**

- Location, description of the current use of the location, project size
- Project Objective, detailed description of the project and its possible extension/expansion plans (if any), extend in time and space,
- Description of all activities related to the project,
- Description of prevention and security measures during the exploitation phases;

✓ **Environmental and social Impacts**

- The environmental effects of the project;
- Description of the effects of the project on the environment resulting from wastes evacuation, noise, dust, air and water pollution;
- Description of the proposed measures to reduce, to avoid or to compensate those impacts.

✓ **Mitigation plan**

- Identification and description of environmental adverse impacts and effects of the project,
- Detailed description of mitigation and compensation measures proposed,
- Plans, equipment and operational procedures appropriate to respond to those impacts.

✓ **Environmental and Social Management Plan (ESMP)**

- Detailed description of the modalities provided in the project for the implementation of the proposed mitigation measures to its potential negative impacts.

✓ **Rehabilitation plan and its monitoring**

- Detailed description of the progressive technics will be used during the rehabilitation process, required resources (human and financial), timelines, responsibilities and indicators for monitoring and evaluation.

✓ **Conclusions and Recommendations**

- The report should also include all information necessary to the project review such as lists of data sources, and any other relevant information to which the consultant's attention should be directed.

1. **Conclusion gives summary of**

- Level of Severity of impacts (Major, moderate, minor) identified in the site
- How feasible the project is vis a vis to each identified impact,
- Overall conclusion of the feasibility of project.

2. **Recommended points** are the advice provided by the expert to help smooth, safe and quality implementation of the project in pre-construction, construction and operation phases.

They are given to

- Project developer
- Project stakeholder (Direct)
- The contractor

Annexes: The ESIA Expert should include in the report the following annexes:

- Public consultation report;
- List of participants in public consultation;
- ToRs;
- ESIA team members;
- Certificates of ESIA Experts

ESIA expert or firms officially recognized and authorized by RAPEP to undertake this study. They must be described in this report as the author of the ESIA report.

3.5.Procedural Guide For Topographic Study

- ➢ Topographic survey shall locate all surface and sub-surface features of the project site, and it shall depict all natural and man-made features and coordinates. Coordinates shall be taken for a number of points in X(latitude), Y (Longitude) and Z(Altitude) coordinates.
- ➢ Collected data will allow to produce maps at different scales with all site features which serve as a basis for further technical studies such as earthworks, setting out of all new building structures of the project.
- ➢ During topographical survey, the following shall be done:

- Carry out boundary surveying of the site.
- Survey spot levels of the ground profile at approximate intervals of 10 meters(subject to change,….).
- Area of topographical surveying shall be carried out beyond the study site area in order to have enough data about the study area.
- Information about existing structures (Ex. Retaining Wall, Road, Building, etc.) shall be collected.
- The existence and nonexistence of building basement around the site shall be investigated.
- Information on existing underground facilities such as Manhole (electrical, gas, sewage water supply, etc.), Electrical and Gas Equipment Lines if any, Water supply Line, telecommunication towers, Storm water and sewage Line, etc. their depth and size shall be determined on site.
- Invert depth of manhole (storm water manhole and sewage manhole) and flow direction.
- Borehole's location survey.
- Production of maps at different scales with contours at 1m interval.
- Modern surveying equipment such as *Differential Global Positioning Systems (DGPS)* and *Total Stations* shall be used in survey data collection.
- Appropriate software such as Arc GIS, AutoCAD shall be used for data interpretation, analysis and production of maps.

3.6.Procedural Guide For Mep & Ict Study

MEP stands for Mechanical, Electrical and Plumbing.

For the building construction project, the MEP study is of crucial importance in the project as it plays a big role and takes a big part in building project. The study is conducted by mechanical specialist for mechanical works. By electrical engineers for electrical works and specialists in plumbing works. In addition to this, the ICT works are conducted to detail all related ICT.

3.6.1. MEP and ICT Components

Table16: MEP and ICT components.

MEP AND ICT components 'study			
Mechanical Study	**Electrical study**	**Plumbing study**	**ICT study**
- Fire smoke detection system; - firefighting system; - fire safety plan; - HVAC System; - Elevators, escalator, lifts	- Power loads calculation - loads schedule; - Electrical single line diagrams - lighting points plans; - Power outlets plans; - bonding –earthing system	- Waste water treatment Plant design and plan - Rain Water harvesting system Tanks and plan; - Water supply system and diagram; - Water Supply Demand & Estimated Waste Water; - Waste water evacuation system and plan.	- IT Data Structure Cabling; - CCTV-Cameras System; - Security Lights & Lightning Protection System;
Author's Key Note: The detailed technical report and drawings or diagrams on MEP and ICT are presented in a separate way.			

3.7.Procedural Guide For Bill of Quantities Elaboration

The bill of quantity (BoQ) also known as estimate, is a document used in construction and engineering projects to provide a detailed breakdown of the quantities and types of materials, labor, equipment, and other resources required to complete the project (Ivor, 2008).

3.7.1. Purpose of BoQ

The BoQ is an essential part of the tendering and contract documentation process and serves several important purposes:

Table 17: Purpose of BoQ.

Purpose	**Details**
Cost estimation	A BOQ helps in estimating the total cost of a construction project by quantifying all the necessary components and their associated costs.
Tendering	Contractors use the BOQ to prepare their bids or tenders for the project. Having a detailed breakdown of quantities allows them to provide accurate cost estimates for their services.
Contractual Agreement	The BOQ becomes a part of the contract documentation. It serves as a reference point for both the client and the winning contractor to ensure that the project is executed according to the agreed-upon quantities and specifications.
Budgeting and Cost Control	During the execution of the project, the BOQ helps in monitoring and controlling costs. Any deviations from the specified quantities or rates can be identified and managed effectively.
Variations and Change Orders	If there are changes to the project scope or additional work required, the BOQ provides a baseline against which variations and change orders can be assessed and priced.

3.7.2. Structural format of BoQ

The bill of quantity (BoQ) is a tabular form organized in a structural format that include the information describing the items, unit measurement, quantity, Rate, total cost and summary totals & grand total for the entire project (Dutta, 2017). It is structured as follow:

Table18: Structural Format of BoQ.

SN	Item description	Unit measurement	Quantity	Rate	Total cost
1					A
2					B
Summary Totals					A+B
3					C
4					D
Summary Totals					C+D
Grand Total for entire project					A+B+C+D

In brief

- **Item Description:** Focuses on giving a clear and concise description of the work or material required(specifications).
- **Unit of Measurement:** The unit in which the quantity is measured (e.g: cubic meters, square, meters, linear meters, etc).
- **Quantity:** The quantity required for each item. The quantity is calculated at each item of project work from measurement taken off project drawings.
- **Rate:** The unit cost or rate for each item, which may include labor, materials, and equipment costs in addition to taxes, contingencies and contractor interest/profits.
- **Total Cost:** The product of the quantity and rate, providing the total cost for each item.
- **Summary Totals**: Subtotals for various sections or categories of work, as well as a grand total for the entire project.

Author's key note

1. The BoQ's quantities are calculate mathematically using the project items'dimensions retrieved from detailed drawings.
2. The detailed BoQ is prepared by quantity surveyors or estimators, expert in quantifying construction elements and assessing costs.
3. The detailed BoQ requires a qualified estimator to have detailed drawings, well items specifications and Rate.

4. BoQ is a tool for ensuring transparency, accuracy and accountability in construction projects, benefiting both clients and contractors.

4. Concluding Remarks

The present research findings show that the feasibility study is a crucial initial step in the planning and development of a building project. It serves as a comprehensive assessment to determine whether the proposed project is viable, practical, and financially feasible before any significant resources are invested. The feasibility study for building project require to conduct an architectural, structural and geotechnical studies, topography, Environmental and social impact assessment, MEP study and bill of quantity elaboration. Each component study requires qualified personnel and compliance with the rules, regulations, guidelines and standards of studies among which legal requirement for technical study, standards and code of analysis and designs, methods and rules of measurement and calculations and laws and orders of environmental protection. This article could help different engineers, project developers, students and researchers to set, execute and respect the appropriate procedures and processes for building projects ‘studies for enhancement of long-term infrastructural stability.

5. Recommendations

The building project are day to day being implemented world widely. A lot of projects can fail due to many root causes among which the gaps in the compliance of study and design procedures. The engineers, students& researchers, entrepreneurs, project managers and project developers in the field of construction were respectively recommended to comply with the procedures of described in this article during the feasibility study, read and refer the procedures mentioned and verify &instruct the compliance with procedures of feasibility study to sustain the long-term stability of building infrastructures.

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