National Universities Commission

Core Curriculum and Minimum Academic Standards CCMAS)

CCMAS Book Series

Fundamentals of Architecture

Book 1 Volume 1

Architecture, Architectural Science Technology and Naval Architecture

General Editor: **Abubakar Adamu Rasheed**
MNI, MFR, FNAL, HLR

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Fundamentals of Architecture Book 1 Volume 1

ARCHITECTURE, ARCHITECTURAL SCIENCE TECHNOLOGY AND NAVAL ARCHITECTURE

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Foreword

The National Universities Commission is empowered by the Education (National Minimum Standards and Establishment of Institutions) Act, CAP E3, Laws of the Federation of Nigeria, 2004, to lay down minimum academic standards in Nigerian Universities and to accredit the degrees therefrom. According to this and in its sustained commitment to the revitalisation of the Nigerian University System, the Commission launched the "Core Curriculum and Minimum Academic Standards (CCMAS)", in December, 2022. The document has been adjudged by both internationally and locally revered scholars, as a standard and fit-for- purpose, designed to meet the demands of the 21st Century.

To ensure the efficient delivery of the CCMAS, it has become fitting and necessary to develop a reference document that would contain innovative and simple topics for all disciplines/programmes to serve as a guide for students and lecturers. This novel idea informs the development of the CCMAS Book Series, which presents to Nigerian universities the fundamentals of each discipline, aimed at deepening the understanding of the CCMAS, for the overall improvement in teaching and learning, and ultimately, for the production of nationally relevant and globally competitive graduates from the System.

The excitement and wide acceptance of the Book Series stems from the fact that several scholars in their respective disciplines sent in their contributions, which are rated topnotch in all ramifications. There is no gainsaying that the Book Series is a welcome masterpiece as it expounds what the CCMAS offers and the many lessons and motivations to draw from its optimal implementation, for the overall good of society.

The effort of the National Universities Commission in the development of the CCMAS and following up with associated innovative initiatives like the CCMAS book series is commendable. Consequently, I congratulate the Executive Secretary, National Universities Commission, Professor

Abubakar Adamu Rasheed *mni, MFR, FNAL* for adding another feather to his feather-filled cap within his reltively short period in NUC. Kudos must be given to the Distinguished Emeritus Professor Okebukola led NUC Strategy and Advisory Committee (STRADVCOM) and staff of the National Universities Commission for driving this process to fruition. There is no way this initiative can become a reality without the contributions of the scholars who developed the texual materials. Consequently, I laud the erudite scholars of Nigerian universities, who have demonstrated their love for academic excellence in sharing their knowledge with humanity through the instrumentality of this project.

I commend the CCMAS Book Series to staff and students of Nigerian universities and indeed to scholars all over the globe as the contribution of the Nigerian University System to academic development and excellence.

Happy reading.

Malam Adamu Adamu
Honourable Minister of Education

Preface

In keeping with its mandate of making university education in Nigeria more responsive to the needs of the society, the National Universities Commission commenced the journey to restructure the BMAS in 2018, introducing in its place, the Core Curriculum and Minimum Academic Standards (CCMAS), to reflect the 21st Century realities, in the existing and new disciplines and programmes in the Nigerian University System. The arduous process, which was birthed through continued stakeholder interactions over the course of four years, produced seventeen documents to cater for each of the disciplines in the Nigerian University System. A key feature of the CCMAS document is the unique structure that provides for 70% of core courses for each programme, while allowing universities to utilise the remaining 30% for other innovative courses in their peculiar areas of focus.

Following the conclusion of the development and review process as well as a series of editing, the CCMAS documents were lau nched in a grand ceremony on the 5th of December 2022. With the launch, the job of the Commission was far from over as this was only the beginning of a three-phase process in the development/review and implementation of the CCMAS document. Having completed phase one, which is the launching of the CCMAS, NUC proceeded to phase two, which involves the development of the 30% CCMAS by the universities. At the same time, the plan for capacity building for effective implementation of the CCMAS as well as the development of textual materials to support the implementation of the CCMAS were taken on board.

The need to have customised (bespoke) texts to support the implementation of the CCMAS was pointed out by an erudite Professor (President of the Nigerian academy of Education) during one of the General Assemblies and was processed through the NUC Strategy and Advisory Committee (STRADVCOM). Emeritus Professor Nimi Briggs was unanimously nominated as the Project Coordinator. The series of textual materials are called the *CCMAS Book Series* and titled *Fundamentals Series* in the first project*.*

The contributors across the 17 disciplines have been drawn from the six geopolitical zones and proprietorship of universities such that there is collective ownership. The major denominator for selection was scholarship in the discipline, which was reflected in the narrative of each book. The various chapters showcase and give examples from local published research so that visibility can be given to ideas from Nigeria and Africa on the topics**.** While definitions and models from "western" scholars are mentioned, these are de-emphasised as much as possible. The time is ripe to show the world, through this book, that Nigerian scholars, over the last 70 years at least, have been in the frontline of research in the published topics and now able to provide generic and contextual definitions, models and examples in the respective disciplines for scholarly work the world over.

The contents target the compulsory courses in the CCMAS and will be published in a series. As much as possible, the books attempt to sync with the levels of delivery of the curriculum that is 100 level; 200 level and so on. The books are written in very simple English, well-illustrated and rendered in the typical course-material format of objectives, content to be learned, summary, evaluation, exercises and references.

The Commission is optimistic that these series will serve as a guide to support the implementation of the CCMAS documents in the Nigerian University System and beyond and adequately equip the trainers and students in making university education more responsive to the needs of society.

Professor Abubakar Adamu Rasheed, *mni, MFR, FNAL, HLR*
Executive Secretary

Editors' Note

The Book Fundamentals of Architecture (book 1) is presented in two volumes. Volume 1 contains materials from three of the programmes in the Faculty of Architecture which are: Architecture Architectural Science Technology, Naval Architecture. The book has 12 chapters which are sequentially arranged according to programme.

Book 1 covers the contents of the compulsory courses for 100-level students with some stretch to 200 level courses. It is a book that has benefitted from multiple authorship by seasoned Professors who have taught the topics in their chapters for at least five years. Contributors are also drawn from public and private universities in all the six geopolitical zones in Nigeria. This is to give a rich flavour of examples and case studies from across the country on the various topics. Each chapter has a main author, who is responsible for coordinating materials from co-authors and acts as a sub - editor for the chapter.

Editorial work has been done in using the American Psychological association style.

The development of the book went through a 12-step process. These are:

Sequence	Activity
Step 1	• Set up Editorial Committee • Layout of Chapters
Step 2	• Call for Expression of Interest (EoI) with the chapter layout advertised from which potential authors will select.
Step 3	• Selection of contributors based on geographical spread and expertise in having taught the top for at least five years. As much as possible, each chapter should be co authored by scholars from different universities.

	• Submission of signed Acceptance Form
Step 4	• Development of first draft (Version 1.0)
Step 5	• Collation of first draft by Editorial Team
Step 6	• Plagiarism check
Step 7	Three-way review by • Scholars external to the writing team • Internal to the writing team: exchange of chapters for review among the contributors • Final-year students selected across universities in the Nigerian university system
Step 8	• Revision of Version 1.0 based on feedback from the three clusters of reviewers. Product is Version 2.0
Step 9	• Check by Editorial Technical Team for compliance with suggestions for improvement made by the three clusters of reviewers. This can be done at plenary with all contributors present.
Step 10	• Second revision by authors based on the feedback at plenary/by the editorial technical team review of Version 2.0. Product is version 3.0
Step 11	• Professional editing/copy editing of Version 3.0. Product is Version 4.0.
Step 12	• Printing/publication of Version 4.0.

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Contents

CHAPTER TEN: BUILDING COMPONENTS AND METHODS

Basic Building Components

Eziyi O. Ibem, *University of Nigeria* **& Oluwafemi K. Akande,** *FUT Minna*

Overview

Adequate knowledge of the basic components that make up buildings is very vital to the understanding of how to design and erect buildings; the various options available in terms of the design and materials; what details are included in a typical building, and the workability of the building. It is also important to know how to achieve safer and aesthetically pleasing buildings; understand how to schedule projects to meet the deadline provided by the owner.

This text equips students with knowledge of the three essential building components: foundations, walls, and roofs; their different types, design, and construction methods as well as the materials that can be used in their construction. It also enhances the students' knowledge of the performance requirements of these components and the International building codes and regulations associated with the material, design, and construction of walls and roofs.

Objectives

This chapter is designed to ensure that students are able to:

1. identify the different types of foundations, walls, and roofs in buildings;
2. explain the conditions in which the different types of foundations can be used in buildings;

3. draw and label the different types of foundations, walls, and roofs in buildings;
4. identify the different materials for foundations, walls, and roofs;
5. describe how foundations, walls, and roofs are constructed;
6. mention the key sustainability issues considered in choosing walls and roofing materials; and
7. identify the local and international building codes and regulations associated with the material, design, and construction of walls and roofs.

Foundations

Buildings have two main components: the sub-structure and the superstructure. Whereas the sub-structure is the part below the ground that is not usually seen, the superstructure is that part of the building which is above the ground and can easily be seen. Foundation is the lowest part directly in contact with the ground (sub-structure) that supports and holds the upper part of the building (superstructure) and helps to transmit its loads directly to the ground. What roots are to trees is what foundations are to buildings. The foundation's lowermost part in direct contact with the subsoil is called the footing. It is the footing that transfers load from the superstructure directly to the soil.

Functions of foundations

Foundations in buildings serve the following basic functions.

1. Hold up and hold together the superstructure of the building.
2. Reduce the load intensity by distributing it over a larger surface area of the soil.

3. Help to transfer load and distribute it evenly to avoid unequal (differential) settlement of the foundation and avoid damage to the superstructure.
4. Anchor the building to the ground, thereby preventing horizontal movement resulting from lateral or horizontal forces such as wind, earthquake, and water current.
5. Prevent damage to the superstructure due to soil movement resulting from shrinkage and expansion of the subsoil made of clay or made-up soil.

Basic Features of a Good Foundation

According to Emmitt and Gorse (2005), the basic functional requirement of a foundation is strength and stability. Given this, the following are some of the basic features of a good foundation.

1. It should be able to support the self-weight and imposed loads of the building.
2. The foundation footing should be rigid enough to withstand any form of excessive differential settlement.
3. Settlement of the foundation should be within acceptable limits to minimise any threat to the superstructure.
4. The foundation depth should be adequate to ensure that seasonal variations in the soil conditions will not have any significant effect on the building.

Factors that Determine Foundation Depths

Generally, several factors determine the depth of foundations. These include:

1. Availability of a favourable soil-bearing capacity.

2. Depth at which the soil type experiences variation in volume due to seasonal changes.
3. Frost penetration depths and levels of fine sand and silt soils.
4. Possibility of future excavation near the project site.
5. The depth of the groundwater table on the site.
6. The depth of topsoil and level of made-up soil on the building site.
7. The expected load on the building (Chudley & Greeno, 2014).

Types of Foundations in Buildings and Methods of their construction

Classification of foundations has its origin in Terzaghi's theory of foundation classification. By this theory, a shallow foundation is one that has a depth that is less than or equal to its width, and a deep foundation is one that has a depth that is larger than its breadth. This means that the classification of foundations is based on their depth in the soil and the ratio of their depths to their widths (See Figure 1).

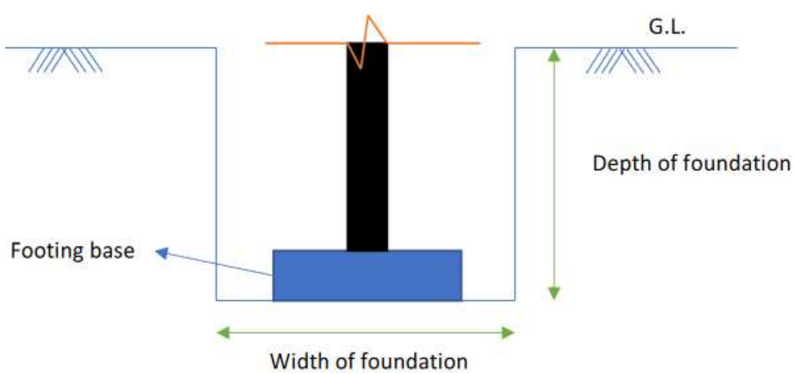


Figure 1: *Section of a foundation showing the width and depth*

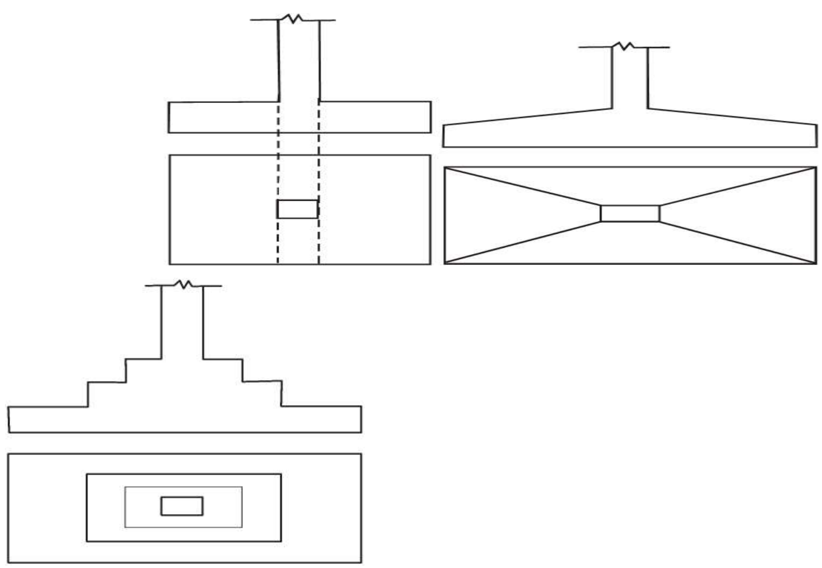
Based on Terzaghi's theory of foundation classification, we have two main types of foundations in buildings. These are shallow foundations and deep foundations.

Shallow Foundations

These are foundations whose widths are greater than or equal to their depths. According to Rajput (2020), examples of shallow foundations include the following:

Isolated footing

This is also known as the pad foundation. It consists of isolated footings of rectangular and square shape that are separated from each other and supports structural components like walls or columns (Chudley & Greeno, 2014). It is the most common and economic type of foundation used where the soil has a good capacity to support loads. The wideness and deepness of a pad foundation are determined by the soil condition (i.e. load bearing capacity) and expected load on the building. Isolated footing can occur in three ways: plain isolated footing; slopped isolated footing and stepped isolated footing as shown in Figure 2 (a, b & c).



(a)Plain Isolated footing (b)Sloped Isolated footing (c) Stepped isolated footing

Figure 2: *Graphic illustrations of plans and sections of isolated footings*

2. Combined footing

In this type of foundation, two or more columns have their footings placed close to each other to the extent that their footings overlap forming a combined footing (Figure 3). This is used when having individual footing for each column is not possible due to site restrictions or when the loads are heavy and the distance between the columns is smaller. The shapes of the footings can either be rectangular, trapezoidal, or combined column/ wall footings.

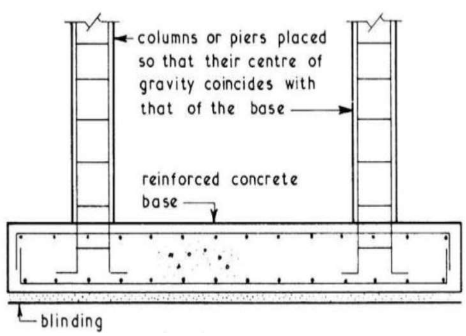


Figure 3: *Combined footing*

Source: Constro Facilitator ,2021. Source: Chudley & Greeno ,2014.

Strip foundation

Strip foundations, which are also known as wall footings are used to transfer loads continuously from walls of concrete and timber frames (see Figure 4).

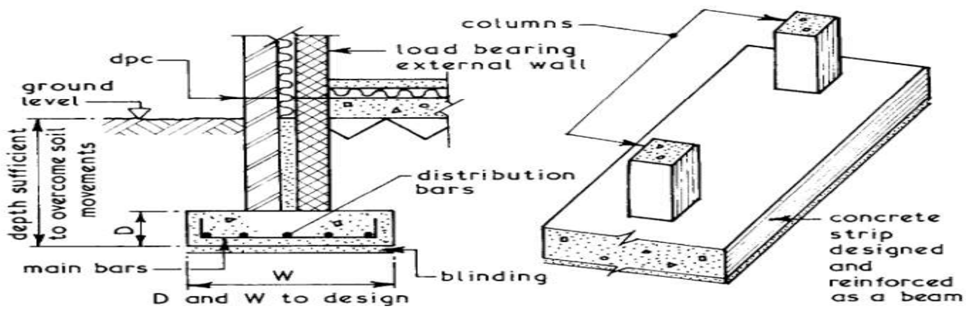


Figure 4: *Strip foundation;* *Source* **:** Chudley & Greeno, 2014.

The size and position of the strips are determined by the overall thickness of the wall. The width of the footing is generally between 2 and 3 times the thickness of the wall. We use strip foundations, particularly where the soil has a good load-bearing capacity. They are used in low-rise or medium-rise buildings and retaining walls where strip foundations of mass or reinforced concrete are economical. The different types of strip foundations are conventional strip, deep strip or trench fill, reinforced concrete strips, and continuous columns.

Cantilever or Strap footing

When two independent columns' independent footings are joined by a beam known as a strap beam, a shallow foundation of this kind is created. The strap beam that connects the two individual foundations provided below the two isolated columns is not allowed to come in contact with the foundation soil or subsoil as shown in Figure 5.

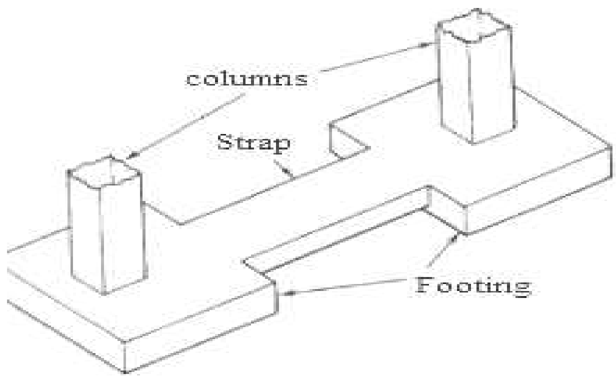


Figure 5: *Plan of cantilever or strap foundation*

Mat or Raft Foundations

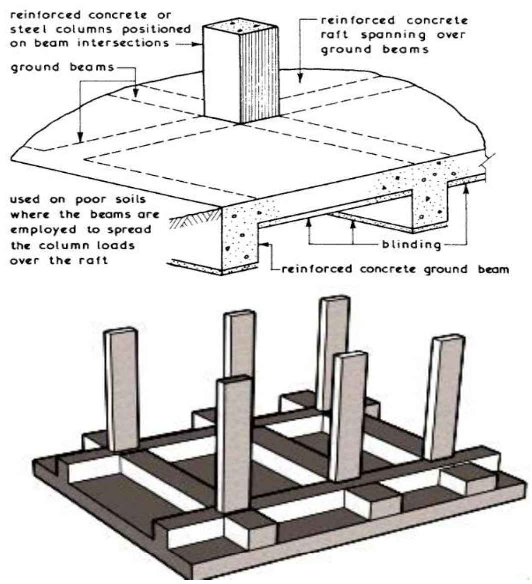
These are made up of solid slabs that support columns or walls underneath them. This foundation type is used mostly where there is compressible ground such as very soft clay soil, alluvial deposits and made-up soil with very low load-bearing capacity and strip, pad or pile will not likely provide a stable foundation (Emmitt & Gorse, 2005). The raft foundations are normally used to provide a very large surface area to spread the load of the building, and thus prevent uneven settlement of the foundation. The advantages of raft foundation are that it requires less excavation, good for soils with low bearing capacity, the load from the upper part of the building is spread over a large surface area of the ground and helps to reduce differential settlement of soil. However, a lot of reinforcement and skilled workers are required for the construction of raft foundations, which can increase the cost of the project.

Types of Raft foundations

There are three major types of raft foundations used in buildings. These are:

1. Beam and slab raft foundation. This consists of reinforced concrete inverted T-beams and slabs that cover the whole area of the foundation. The inverted T-beams run in both directions and at the points where they meet are columns that carry the load from the upper part building. The entire arrangement of slab and beams form a unified structural entity. It is used when the loads carried by columns are heavy and the spacing of the columns is relatively wider. The beams are usually arranged parallel to each other in both directions and at the meeting point of any two beams is a column as shown in Figure 6.

They are two types of beam and slab raft foundations. The first is the raft foundation with down-stand beams and the second is the raft foundation with up-stand beams (Chudley & Greeno, 2014). The raft foundation with the down-stand beam has the ribs of the beams below the raft slab, hence, the raft slab doubles as either the basement floor slab or the ground floor slab. The raft foundation with up-stand beams has the ribs of the beams above the raft slab. This is disadvantageous, firstly, because of the need to provide a ground floor slab, and secondly, it constitutes some challenge in dealing with the cells provided by the up-stand beams.



(a) raft foundation with down-stand beams **(b)** raft foundation with up-stand beams

Figure 6: *Beam and slab raft foundation*

2. Flat raft foundation. This is made up of thick reinforced concrete slabs that cover the entire space of the foundation and are strengthened by layers of bars running perpendicular to each other beneath the top surface of the mat and another layer above the bottom. The slab usually supports the columns which are placed close to each other as shown in Figure 7.

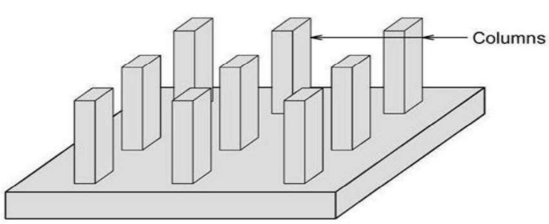


Figure 6: *Graphic illustration of Flat Raft foundation*

3. Cellular raft foundation: This has two-way beams at the foundation with a solid slab placed above and below (Figure 8).

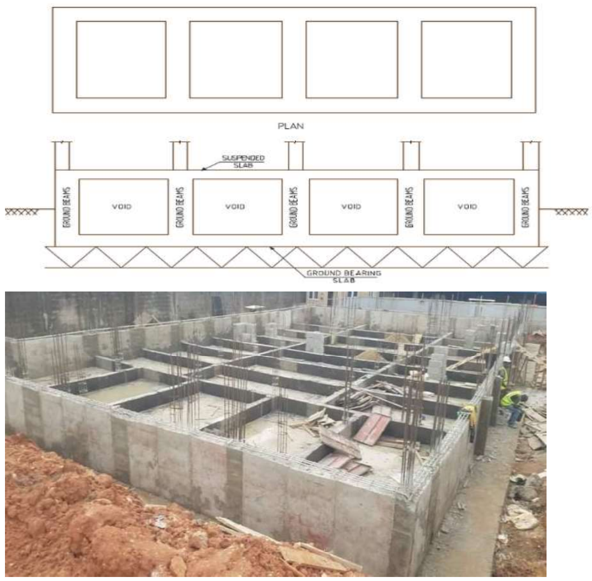


Figure 8: *Cellular raft foundation;* *Source*: Omotoriogun , 2021.

Both the upper and lower slabs are connected by intermediate beams, making the foundation look like an I-beam structure. The top slab can be covered using precast soffits or other types of permanent formwork and it is filled with lightweight infill blocks. The cellular raft foundation is normally used where there is heavy mining activity; the soil has bearing capacities, and there is a need to check soil uplift pressure.

Deep Foundations

These are all foundations in which the ratio of their widths to depths is less than one. They are used to transfer the load on buildings down through the upper weak layer of topsoil to the stronger strata of subsoil. There are generally three types of deep foundations in construction, but the pile foundation is the most common type used in buildings. The three types of deep foundations are 1) pile foundation: used in buildings

2) pier foundation, used in bridges and fly-overs to resist heavy traffic loads, and 3) drilled shaft or caisson foundation which is used where the pile foundation is not enough to bear the heavy load of the structure such as bridges and dams under the water.

Pile foundations

A pile foundation consists of several columns built or inserted into the ground to transfer the loads on the building to a lower subsoil level (Chudley & Greeno, 2014). It is used where hard strata are available below the limit in which the shallow foundation is not economical, and piles are used for the purpose of transferring loads from the building to a hard surface in the ground (Figure 9).

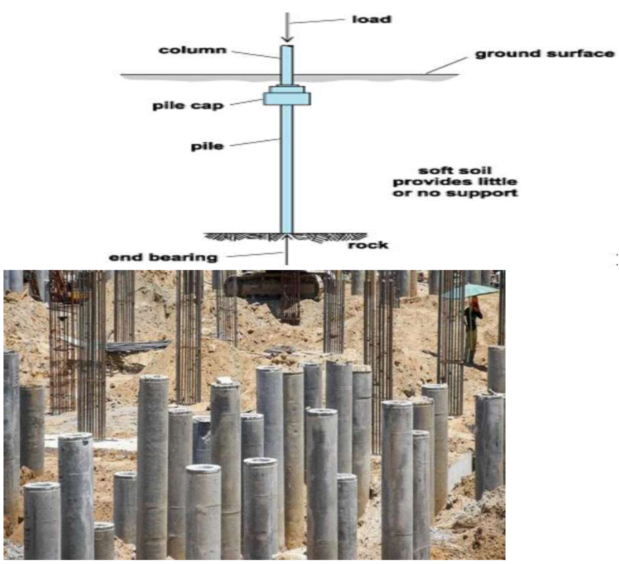


Figure 9: *A typical pile foundation*; Source: Constro Facilitator, 2021.

Pile foundations are used where there is shrinkable clay soil, deep-rooted trees, sub-soil is soft, and the existence of uncertain bearing capacity of soil a few meters below the topsoil (Emmitt & Gorse, 2005). They prevent the building from experiencing uplift due to lateral loads from wind and earthquake forces; and limit uneven settlement of the foundation. Pile foundations could be pre-fabricated or cast-in-situ and can be constructed using timber, steel, concrete, reinforced concrete, or a combination of any two of these materials.

(a) **Steel piles**: These are made up of H-piles, pipe piles, and sheet piles made of rolled steel sections. These piles have a shoe at the lower end for ease of driving and to prevent rusting epoxy coating is recommended.

(b) **Concrete piles**: These occur in two main types: precast and cast-in-situ. Pre-cast (prefabricated) piles are cast in a factory or prestressed and then transported to the site. The cast-in-situ piles are constructed on-site by boring holes through into the soil and then filling them up with concrete. For reinforced concrete piles, the already prepared cages are filled with concrete after inserting the steel reinforcements.

(c) **Timber piles:** These are prepared from wood that is straight and devoid of defects and cracks. Timber piles are usually provided with steel shoes to prevent damage during driving. For durability, a coating of creosote oil or bitumen coating is usually recommended.

(d) **Composite piles:** Composite piles are made up of two different materials, such as concrete and timber and concrete and steel. It is a common practice to place the concrete in the upper part, while the lower part is made up of steel or timber.

Modes of load transfer in pile foundation

There are three modes of load transfer in pile foundations (Rao, 2010). These are end bearing mode, friction mode, and combined end bearing and friction mode (see Figure 10).

(1). End-bearing or Point-bearing piles. This transfer loads to a hard stratum some depth below the ground level based on the bearing capacity of hard strata. They behave as columns and transfer loads with the same mechanism as structural columns in a building.

(2). Friction or floating piles: Unlike end-bearing piles, friction piles do not require a hard stratum to be able to transfer loads as they transfer loads via friction with the surrounding soil. The load to be transferred must be equal to skin friction between the piles and the surrounding soil. This type of pile is also referred to as floating piles because they do not have contact with a hard stratum of the soil. They are used when getting to the hard strata is not economical because of their depth.

(3). Combined end bearing and friction piles: They transfer load using a combined mechanism of end bearing and skin friction mechanisms as previously explained.

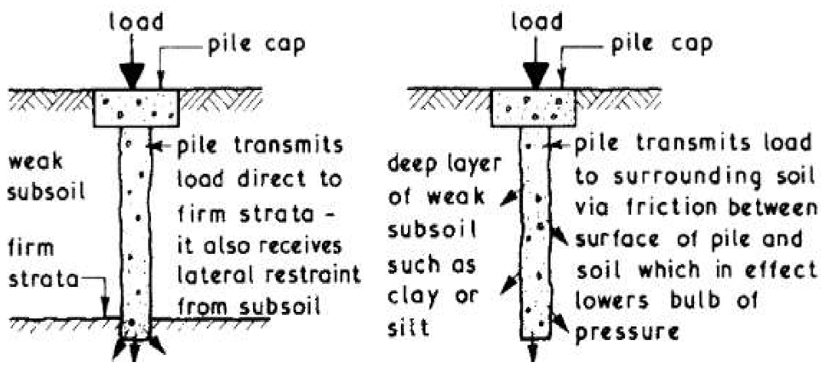


Figure 10: *Modes of load transfer in pile foundations Source*: Chudley & Greeno, 2014

Foundation Design Principles

The purpose of a foundation is to have a reliable structural arrangement that ensures that loads on the building are transferred to the sub-soil safely and economically without any form of vertical and horizontal movement capable of threatening the structural stability of the building. Therefore, the foundation design procedure includes the following steps:

1. Evaluation of the site conditions with respect to the soil investigation report.

2. Estimation of the anticipated loads on the building at all times.

3. Choose the appropriate type of foundation taking cognizance of the following factors

a) Soil condition (i.e. bearing capacity).

b) Type of building (e.g. residential, institutional, commercial, etc.).

c) The anticipated load on the building in its entire life span.

d) The cost implication of the foundation.

e) The duration of the building contract.

f) Buildability of the foundation.

g) Materials to be used.

4. Size the members of chosen foundation bearing in mind the loading condition, soil bearing capacity, and form of movements the building might likely experience in the future (Chudley & Greeno, 2014).

Walls in Buildings

A wall is an element used to divide or enclosed spaces or to form the external covering (envelope) of the building. It is part of the building structure that supports a load and offers security, shelter, and soundproofing.

Types of Walls and their functions in Buildings

Based on their functions walls are divided into the following types (i) load-bearing walls (ii) non-load-bearing walls (iii) cavity walls (iv) shear walls (v) partition walls (vi) panel walls (vii) veneered walls and (viii) faced walls

Load Bearing Walls

Load-bearing walls are force-resisting or load-carrying elements that carry their own weight, and, vertical and lateral load on the superstructure from the floors, beams, slab, and roofs. Load-bearing walls are designed as interior or exterior walls. Load-bearing walls are in different types namely: (i) precast concrete wall (Figure 11) (ii) retaining wall (Figure 12) (iii) masonry wall (Figure 13) (iv) pre panelized load bearing metal stud walls (Figure 14) (v) engineering brick wall (Figure 15) and (vi) stone wall (Figure 16).

Figure 11: *Precast Concrete Wall* **Figure 12**: *Retaining wall*

Source: Kingdom Precast (2023) *Source:* PERI Nigeria (2023)

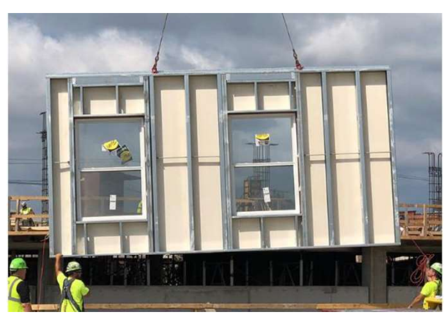


Figure 13: *Masonry Wall* **Figure 12**: *Pre-panelised*
metal stud Walls
Source: Richard (2018) *Source*: All Steel mid-rise
(2023)

Figure 15: *Engineering brick Wall*
Farad Contractors (2010)

Figure 16: *Stone Wall*
Dream Civil (2022)

Non-load/Structural Bearing Walls

These are walls that do not carry any load outside their weight. They are mostly used as internal walls to divide the spaces in buildings into smaller spaces for different activities. They are built with lighter materials such as plywood, metal sheets, and others, and hence are cost-effective. Any non-load-bearing walls can be removed from the building without endangering the structural stability and safety of the building. The types of walls in buildings that are not designed and constructed to carry loads include (i) hollow concrete blocks when used in multi-story buildings (Figure 17) (ii) façade bricks (Figure 18) (iii) hollow bricks (Figure 19) and brick facing walls (Figure 20).

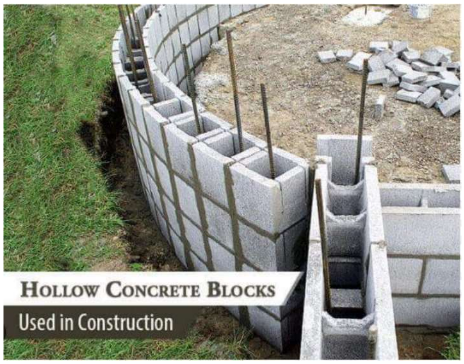


Figure 17: *Hollow Concrete Block*
Patel (2020)

Figure 18: *Façade Bricks*
Farad Contractors (2010)

Figure 19: *Hollow Bricks*
Alamy (2022)

Figure 20: *Brick Walls*
Source: Earth Bricks Venture (2023)

Cavity Walls

Cavity walls are made of two leaves or skins with a void or cavity between them. The outer wall is normally connected to the inner wall separated by an air space. Cavity walls improve thermal and acoustic insulation while excluding moisture from entering the interior spaces of the building through the wall. They are fire-resistant and economically cheaper than other solid walls (see Figure 21).

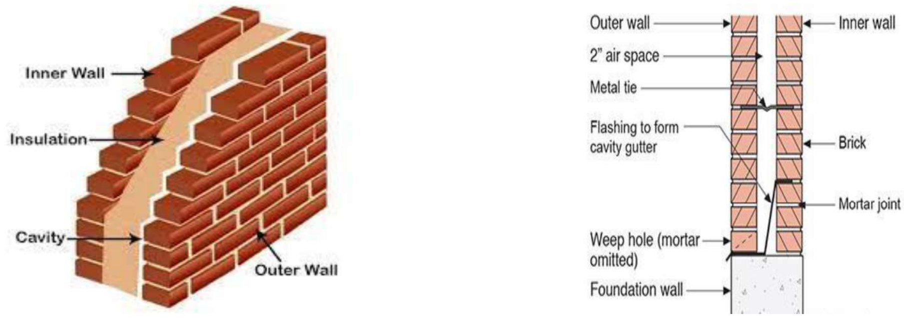


Figure 21: *Cavity wall*

Shear Walls

These are framed walls meant to transfer lateral loads from exterior walls, floors, and roofs to the foundation. Shear walls are very important in high-rise buildings to provide bracing due to their very high stiffness and strength. They act as a beam cantilevered out of the foundation and their strength comes from their thickness Shear walls are usually made up of wood, concrete, or masonry. They are very good at resisting seismic (earthquake) and wind loads (see Figure 22).

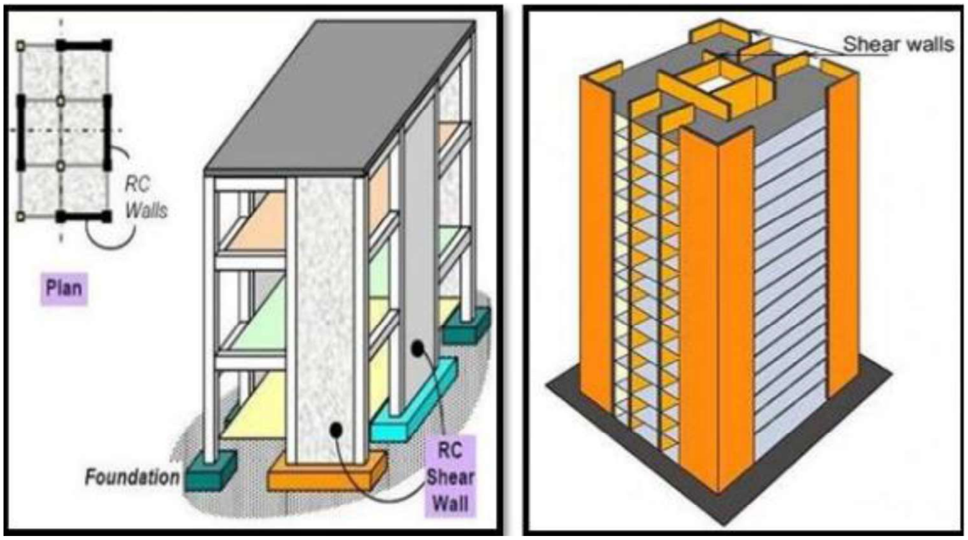


Figure 22: *Reinforced concrete shear wall in building Source:* Murty C. V. R (2005)

Partition Walls

Partition walls are used to subdivide large spaces into smaller ones in buildings. They can be constructed with different materials such as bricks or stones and are stable and strong to support their self-weight and those of wall fixtures. They have high soundproof and fire-resistant properties.

Panel Walls

Panel walls are not designed to support additional loads except their self-weight. Both nails and adhesive are used to install the panel. The paneling design possibilities include rustic, boards, and frames. They can be manufactured from hardwoods or economical pine. Prior to installing panel walls, the space should be painted.

Veneered Walls

These are single, non-load-bearing exterior brick, stone, or artificial stone walls. They have an air space behind them and are called anchored veneer. They are usually light-weighted and take a shorter time to construct.

Faced Walls

These have facing and backing made of two different materials held together by a binding material to ensure they act as a unit. They create a streamlined look and they are easy to install. Figure 23 shows a faced wall with two bricklayers at the front and a fiberboard at the back. The bricks and fiberboard are held together by concrete.

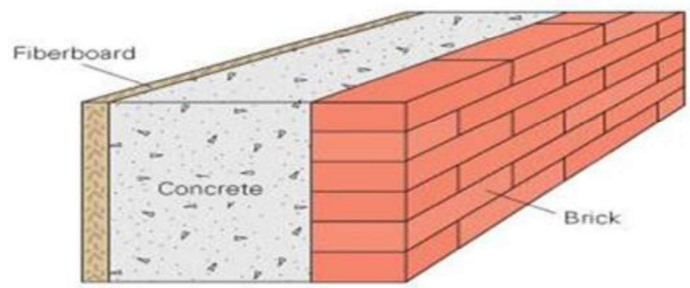


Figure 23: *A faced wall of fiberboard and brick held together by concrete*

Materials for Construction of Walls

There are different ways to construct walls with different materials. Walls can be formed of individual units of materials such as bricks, clay or concrete, or stones, usually in courses joined together with binding materials such as mortar. Monolithic walls are formed of materials set in layers or as sheets and can be made of conventional earth materials or concrete, or even wood. The earth walls are affordable and sturdy if put on a stable base and shielded from the rain by a rendering or wide roof overhangs.

A frame wall is built as a series of relatively tiny, mostly wooden, elements placed closely together to form a load-bearing unit with a face or sheathing on one or both sides. A membrane wall is created as a sandwich of two thin skins or sheets made of reinforced plastic, metal, asbestos-cement, or any other suitable material attached to a core of foamed plastic. It can also be achieved using framed or earthen materials comprising light sheeting that is fastened to the face of the wall and forming the enclosed elements. This is often referred to as cladding.

Factors that determine the type of wall to be used

The following factors determine the type of wall in a building (i) the availability and cost of the materials (ii) the availability of a skilled workforce to use the material (iii) climate and (iv) the type of building and its function.

Sustainability Issues in the Choice of walling materials

The sustainability issues associated with the choice of wall materials include the following:

1. The source of the materials and energy required its extraction, processing, and transportation to the site.
2. Level of CO_2 emission involved in the production of wall materials.
3. Initial and maintenance costs of the wall.
4. Thermal insulation properties of the material for the thermal comfort of building users.
5. Aesthetics of wall materials.

International and Local Building Codes and Regulations Associated with the material, design, and construction of walls

International Building Code (IBC): Chapter 14 of the IBC is on Exterior Walls. It covers the fundamental requirements for exterior walls, such as the types of wall coverings that should be used, how they should be installed, and the weather and fire-resistant properties of walls.

*Nigeria's National Building Code 2006***:** Section 10 of the NBC is on building materials and components requirements. This section covers the requirements of various materials used in building construction and establishes the expected quality of such materials to be characterised by their durability, functionality, aesthetics, resistance to fire, and grade.

Roofs in Buildings

The roof is a covering on the top of a building that protects occupants and interior spaces against elements of weather such as rain, snow, sunlight, wind, and temperature.

Performance Requirements of Roofs

The following are the basic functional requirements of roofs.

1. Have enough strength and stability to support the self-weight and imposed loads.
2. Adequately protect the building and its occupant from rain, sun, wind, etc.
3. Be durable against the adverse effects of the elements of weather.
4. Be water-proof and have good drainage features.
5. Adequate thermal insulation properties.
6. Have adequate fire-resistant property.
7. Provide adequate insulation against sound.
8. Have provision for natural daylighting if required.
9. Should be accessible for maintenance.
10. Provide adequate security.
11. Be aesthetically pleasing (Emmitt & Gorse, 2005).

Types of roofs

The choice of any roof type for a building is a function of climatic conditions and material availability. There are three main categories of roofs. These are:

1. 1. Pitched or sloping roofs: Pitched or sloping roofs have their sides inclined to the horizontal plane and with a pitch of over 10 degrees used in different kinds of buildings
2. 2. Flat roofs or terraced roofs: These are roofs with a pitch ranging from 0 degree to 10 degrees. Flat roofs can be used on buildings of any size and shape.
3. Curved roofs: These have curved surfaces and are used to create aesthetic effects. They can take different forms such as cylindrical and parabolic shells and shell domes, doubly-curved shells (e.g. hyperbolic, paraboloids, and hyperboloids of revolution, and folded slabs and prismatic shells). They are used in different building types, including civic buildings, sporting facilities, factories, and others.

Different Roof forms

Roofs have different forms, but the common forms are shown in Figure 24.

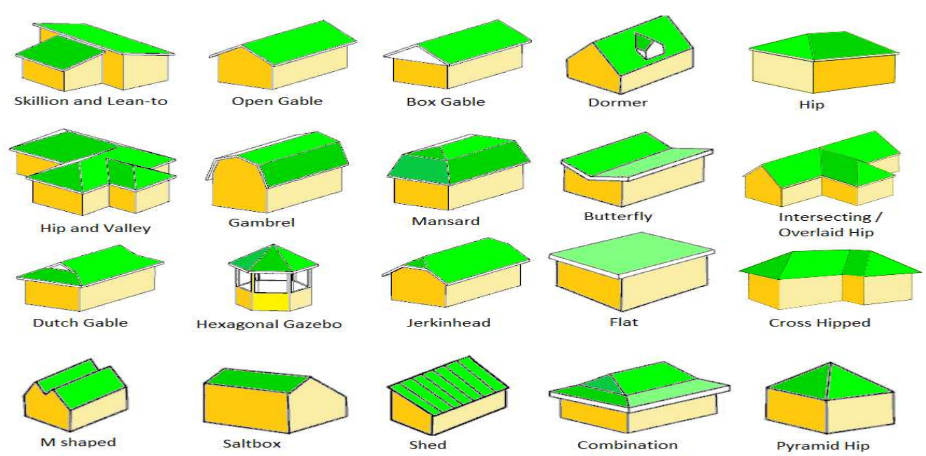


Figure 24: *Roof forms* *Source*: Rahman (2021)

1. Lean-to or shed roof. It is the most common type of roof that slopes on one side only.

2. Gable Roof: This has slopes in two directions. The slopes meet at the ridge and the ends face form a vertical triangle.

3. Hip Roof: This is formed by having the four sloping surfaces in four directions. The end faces form slopping triangles.

5. Mansard Roof: This is similar to a hip roof with slopes at the face. However, each slope has a break resulting in sloping ends.

7. Gambrel Roof: Like a gable roof, it slopes in two directions but each slope has a break and at each end, there is a vertical face.

6. Butterfly Roof: This is formed by two lean-to roof meeting at the valley.

8. Flat roof: This has a slope of less than $10^{o.}$ The slope required for the rainwater to drain off easily and rapidly. Flat roofs serve as terraces for different activities.

9. Shell and domes roofs: These are roofs with curved geometry with a pleasing appearance.

10. Clipped gable roof: This is also known as Jerkinhead or bullnose roof. It has the shape of a gable, with two sides meeting at the ridge with bent-in peaks. Small hips are created at the ends of the ridge.

11. Dutch gable roof: This is a combination of gable and hip roofs. The main roof structure is hip but with a miniature gable roof (gablet) placed on top of the hip roof.

Materials for construction of roofs

Roof materials consist of those used as roof structures and those used as roof coverings. Roof structures are mostly timber, steel, and concrete. The different materials that can be used as roof coverings include the following:

1. Eco-friendly or green roofing materials**:** These include materials made of trees and plants such as thatch, grasses, timber
2. Shingles: This is the generic term for roofing materials with sections overlapping each other. Examples include asphalt shingles and asphalt roll
3. Clay and concrete tiles: Made from clay and concrete materials that are very durable.
4. Membrane roofing. Made of large sheets connected to form a continuous surface (e.g. Polyvinyl chloride (PVC) roofs,)
5. Concrete or fibre cement: This is made of cement reinforced with fibre material
6. Reinforced concrete: Consists of cement and steel and is mostly used for flat and curved roofs. There are three main categories, precast/prestressed, cast-in-situ, and shell roofs.
7. Metals roofs: These are corrugated metal sheets **(**e.g. galvanised iron, copper, aluminium, copper, stainless steel).

Determinants of the choice of roof types and materials

Several factors determine the choice of roof types and materials (Mijinyawa, Adesogan & Ogunkoya, 2007). These include

1. Durability and ability of roofing material to withstand weather conditions.
2. Properties of the material such as weight, thickness, durability, slope, and shape.
3. Eco-friendliness of the material (e.g. energy efficiency, embodied energy).
4. Cost of the material (initial and maintenance costs inclusive).

5. The desired aesthetic quality.
6. The type of roof (i.e. pitch and slopes of the roof).

Sustainability Issues in the Selection of Roofing Materials

The sustainability issues associated with the selection of roofing materials are concerned with how green, or eco- / environmentally friendly the materials are in terms of the sources of their raw materials; how there are manufactured; their performance over their lifetime; and how they are disposed of at the end of their lifespan. Given this, in choosing roofing materials, the following sustainability issues should be considered.

1. The source(s) of the raw materials used in producing the materials: Renewables sources are preferred.
2. The quantity of energy used in their production and transportation to site and assemblage (embodied energy). Preference should be given to locally sourced materials to reduce energy consumption and CO_2 emission during production and transportation and construction process.
3. Ability to reflect and insulate from heat to reduce heat gain into the building. For energy efficiency, light in coloured and highly reflective materials is recommended.
4. Durability: Be sure that the roofing material requires less frequent maintenance and that no toxic products are required to maintain it.
5. Biodegradability of the material: Highly biodegradable materials are preferred to reduce the amount of waste in the dump site.
6. Recycled content: Check to see if the roofing material contains recycled content. The higher the percentage of recyclable content the more sustainable.

7. Cost, including initial and maintenance costs.

International and Local building codes and regulations associated with the material, design, and construction of roofs

International Building Code (IBC): Chapter 15 of the IBC deals with 'Roof Assemblies and Rooftop Structures. It provides the basic requirements for roof construction in buildings. It identifies the requirements for roof coverings and the need to use weather-protective and fire-resistant materials for roof construction.

National Building Code 2006: Part 2, Section 5, of the National Building Code which is on the construction process by elemental classification deals with the design and construction requirements for the various building components including the roof. It specifies the types of materials for roof construction for durability and fire protection. Standards for roof coverings are also specified in the NBC (2006).

Building Regulations*:* Local building regulations deal with the quality and standards in the use of any specified materials or methods of erection or conformity with any specification, standard specification, code of practice, or standard method, these guides establish the specific materials and techniques of erection of structures. Relating to the material, design, and construction of roofs, building regulations specify the standards that buildings must adhere to as preventative measures against fires or other emergencies, including the resistance of buildings against the outbreak and spread of fires.

Summary

This section of this book dwelt on three basic building components: foundation, walls, and roofs. The Chapter was broken into three parts. The first part focused on identifying and explaining the various components of building foundations, their functions, and design requirements. It went on to describe the different types of foundations, their construction methods, the materials used in their construction, and the condition in which they can be used in buildings. The second part focused on walls. It identified and described the different types of walls, their construction methods and material, and the sustainability issues considered in the choice of walling materials. It concluded by identifying the two international and local building codes and regulations associated with the material, design, and construction of walls. Last but not the least dwelt on roofs. The discussions were on performance requirements for roofs, types of roofs, roof forms, materials for roof construction, factors that influence the choice of roof types and materials, and sustainability issues in the selection of roofing materials. The Chapter ended with the identification of international and local building codes and regulations associated with the material, design, and construction of roofs.

Exercises

1. Identify the two main types of foundations that you know.
2. Identify different types of shallow and deep foundations explaining the conditions in which they can be used in buildings.
3. Describe the factors that determine the choice of foundation for buildings.
4. Identify and describe the different types of walls in buildings.
5. Identify and explain the sustainable issues considered in the choice of walling and roofing materials.
6. Survey the buildings in your university and document the various types of walls and roofs used.
7. Identify the performance requirements of foundations and roofs.
8. Identify the materials that can be used in the construction of foundations, walls, and roofs.

9. Mention any two local and international codes and regulations associated with the material, design, and construction of walls and roofs in buildings.

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