CHAPTER 5: CONSTRUCTION MATERIAL SCIENCE

5.1 Introduction

This unit describes the competence in applying building materials science. It involves identifying essential construction materials, selecting quality construction materials, testing construction materials and demonstrating knowledge in use of construction materials.

5.2 Performance Standard

Identify essential construction materials, identify properties of construction materials, manufacture construction materials, and select quality construction materials, use construction materials, test construction materials and handle construction materials safely based on construction requirements and project scope.

5.3 Learning Outcomes

5.3.1 List of Learning Outcomes

a) Identify essential construction materials
b) Identify the properties of construction materials
c) Manufacture construction materials
d) Select quality construction materials
e) Use construction materials appropriately
f) Test construction materials
g) Handle construction materials safely

5.3.2 Learning Outcome No 1: Identifying Essential Construction Materials

5.3.2.1 Learning Activities

Learning Outcome No 1: Identifying Essential Construction Materials	
Learning Activities	**Special Instructions**
1.1. Obtain and interpret Bills of Quantities and working drawings 1.2. Identify essential construction materials (stones, bricks, clay and clay products, lime, cement, timber and timber products, metals and alloys, paints and varnishes and roofing materials)	Visit construction sites. Conduct practical lessons.

5.3.2.2 Information Sheet No5/LO1: Identifying Essential Construction Materials

Introduction

This learning outcome covers engineering drawings interpretation, bills of quantities and construction materials.

Definition of key terms

Bill of Quantities: This is a document typically prepared by the quantity surveyor that provides a project's specified measured quantities of the items of work in accordance with the drawings and specifications in the tender documentation. Also referred to as BOQs or BQ.

Drawings: These are visual representations of structures or objects which provide dimensional and graphical information that can be used by a contractor in construction works or suppliers to fabricate components of the work.

Specifications: They describe the specific materials and level of workmanship required i.e. by compliance with manufacturers' requirements.

Construction material: This refers to any material used for construction purposes.

Content/Procedures/Methods/Illustrations

1.1. Bills of Quantities and working drawings are obtained and interpreted

Bills of Quantities list all the materials required to complete the design for a construction project of any structure. The BQs assist tenderers in the calculation of the construction cost of their tender. The quantities may be measured in number, length, area, volume, weight or time.

How to prepare Bills of Quantity (BQs)

Preparing a Bill of Quantity requires that the design is complete and a specification has been prepared.

A standard method of measurement (SMM) is a reference document used to determine the localized technique of construction measurement procedure needed to produce a valid and good Bill of Quantity which is then incorporated into the contract document for the project. Preparing a BQ based on SMM will help a contractor price the tender in a realistic way. A standard method of measurement is reflective of actual works.

Set up a spreadsheet for the BQ (bill of quantity)

This includes columns to fill the item number, the rate for the item and total cost for the item.

Table 5: Bill of Quantity

Item No	Description	Unit	Quantity	Rate	Total Cost

The columns on the rate and total cost will be filled in by the contractor or binding on the project. Technically you won't have any values in those columns while drafting your BQ

List all the materials needed to complete the project

From the architect's plan, write a list of the building materials required and the amounts needed for each. The architect can also specify the type of materials recommended for the project. For example, when building a residential house, one might need bricks, concrete, flooring materials etc. It is important to identify the unit of measurement for each of the materials. Once you have determined the materials needed, fill your spreadsheet i.e,

Table 6: Materials needed to complete a project

Item no	Description	Unit	Quantity	Rate	Total cost
A	**Excavations** Clear the site of all shrubs and undergrowth	S.M.	249	50	
B	Excavate vegetable soil average 150mm deep	S.M.	249	100	

Categorize the project into specific sections.

Since different parts of the project will be handled by different subcontractors, it is good to split the list into sections. This makes it easier for the contractors or subcontractors to know exactly what their cost will be for the project.

Make an initial cost estimate based on the architect's design

The standard method of measurement provides the prices of materials and labour required. Summing up all these cost estimates gives a rough idea of the project cost even before it starts. Materials suppliers, on the other hand, give different costs during the bidding. Comparing bids from contractors ensure that one gets the best bid for their project.

Table 7: Initial cost estimate

Item No	Description
A	Element No 1
	Substructures
B	Excavations
A	Element No 2
	Superstructure
B	Reinforced concrete

Example: Proposed residential house

Table 8: Bill of Quantities

Item	Description	Unit	Quantity	Rate	Total cost
	Element No 3 **Internal Finishes** **FLOORS** Cement and sand (1: 4) screeding smooth trowelled				
A	32mm thick sand cement screed prepared to floor	SM	120	300	36,000.00
B	32mm thick screed prepared to receive ceramic tiles	SM	120		66,000.00
	TOTAL FOR ELEMENT NO 8 (CARRIED TO SUMMARY)				

Advantages of Bills of Quantities

- Assist tenderers in the calculation of construction costs for their tenders
- Provides a schedule of rates assisting with the valuation of variations s
- Helps in valuing interim payments for the labourers
- For tenderers, it helps to create a low-risk and low-cost tendering environment

Working Drawings

These are construction drawings provided by the architect, to the contractor to facilitate construction of works, or given to suppliers to fabricate components of the works.
Working drawings describe plans, sections, and elevation.

Types of Construction Drawings

- **Architectural drawings:** These demonstrate where the building will be located and where all the building parts will be placed provided by the architect to the contractor on site
- **Structural drawings:** They are drawings Prepared by the structural engineer showing information about the structure, like the strength of different structural elements, size and placement of reinforcement
- **Electrical drawings**: These are prepared by the electrical engineer showing details and location of electrical wiring, fixtures, sub-station etc
- **Plumbing and Sanitary drawings**: Prepared by the services engineer, they show location of sanitary, piping for water supply systems, fixtures and process to connect every fixture.

Essential construction materials

Building /construction materials refer to any substance either natural or manmade which is used for construction purposes to create structures and buildings.

Some of the most building materials include;

a) Stone

It is the most commonly used material in Kenya.

There are two types of stones;

- Manually cut stones

b) Fired bricks

Commonly used for constructing walls and also arches, as a substitute to stone. How bricks are made-clay is compressed to form blocks. It is then left to dry in the air. After drying, they are burnt or fired in a kiln to permanently harden them.

c) Metal

Steel is the most popular metal used in the structural framework of buildings. It is preferred in construction because it is strong, flexible and long-lasting. Other metals used are aluminium and copper because of their rust and corrosion resistance. Copper is used for electric wires, piping for water supply etc. Aluminium is used as roofing sheets, gutters, decorations etc.

d) Sand

Used together with cement to make mortar, or masonry work and plaster.

e) Cement

Cement is mixed with sand and gravel aggregates to form concrete, used in building floors, roads, bridges etc.

- It is the most essential building material.
- It is used in masonry work as an adhesive to hold bricks, blocks and stones in place.
- It is also used in plastering

f) Wood

Wood is used mostly in flooring, panelling and finishes. It is also popularly used in the construction of roofs (trusses), doors etc

g) Roofing tiles

Most commonly known as clay tiles**,** they are durable and good in harvesting rainwater. The tiles are thin flat slabs of fired clay, concrete, cement or metal laid in rows to form a cover. Other types of construction materials include; glass, bamboo, EPs panels, glazed ceramic tiles etc.

The choice of building materials to be used in construction is determined by the following factors;

- Availability
- Cost
- Durability

Conclusion

The learning outcome covered engineering drawings interpretation, bills of quantities and construction materials.

Further Reading

1. Read more on building materials in modern industry from building material (2002) by SK Nugget.

5.3.2.3 Self-Assessment

Written Assessment

1. What is the purpose of a working drawing?
    a) To convert a design into construction information and communicate to different players in construction.
    b) Present to the client for presentation works
2. Which material among the following is preferred as a load-bearing?
    a) Fired bricks
    b) Glass
    c) Manually cut stones
3. Cement is mixed with gravel and sand aggregates to form?
    a) Concrete
    b) Tiles
    c) Blocks
4. What is the role of an architect in relation to identification of materials?
    a) Provide a Bill of Quantities
    b) Generate construction drawings which will be used by the contractor

5. Which of the following is not a virtual building material?
    a) Images
    b) Text
    c) Wood
6. Is finishing drawing also a type of working drawing?
    a) Yes
    b) No
7. Which of the following is not a roofing material
    a) Clay tiles
    b) Aluminium sheets
    c) Cement
8. Describe the difference between presentation drawings and working drawings?
9. Justify the roles of a quantity surveyor in relation to Material identification.
10. Using relevant examples, construct five types of working drawings
11. Steel is a preferred metal in construction. Justify.
12. Mention and explain 5 popular building materials in modern industry

Oral Assessment

1. Summarize the properties of building stone as a Building material.
2. Mr Waweru wants to construct a two bed room house. As an architecture, you have been contracted to oversee the project and advice. Prepare a list of the materials he is likely to use and justify the reasons.

Practical Assessment

Generate a complete Bill of Quantities from the information provided by the lecturer
Use the standard method of measurement (SMM) as a reference document

5.3.2.4 Tools, Equipment, Supplies and Materials

- Computer
- Labouratory testing equipment
- Labouratory apparatus
- Hand tools
- Machine tools

5.3.2.5 References

S.K. Duggal (2000). Building Material, New York: New International Publishers

The federation of civil engineering contractors (2015) Civil Engineering Standard Method of Measurement: ICE Virtual Library

The constructor (2009), Building Technology Guide. Nairobi: New International Publishers

5.3.3 Learning Outcome No 2: Identifying Properties of Construction Materials

5.3.3.1 Learning Activities

Learning Outcome No 2: Identifying Properties of Construction Materials	
Learning Activities	**Special Instructions**
2.1. Identify physical properties (porosity, surface texture, strength, density, thermal conductivity and wear and tear) of construction materials 2.2. Identify chemical properties (corrosion resistance and chemical resistance) of construction materials 2.3. Identify mechanical properties (toughness, hardness, fatigue, strain and stress and creep and stress rupture) of construction materials	• Demonstration • Practical assessment • Direct instruction

5.3.3.2 Information Sheet No5/LO2: Identifying Properties of Construction Materials

Introduction

This learning outcome covers physical properties of construction materials, chemical properties of construction materials, mechanical properties of construction materials engineering drawings interpretation, bills of quantities and construction materials.

Definition of key terms

Code of practice: It is a document containing guidelines on how professionals in a specific industry are supposed to conduct themselves in different situations when they appear as consultants.

Chemical properties: It is any material's character that showcases itself during or after its interaction with the environment or other materials.

Mechanical properties: These are physical properties that construction materials exhibit when forces (tension, compression and shear forces) are applied in different ways. Some of these include tensile strength, elongation, fatigue limit and hardness.

Physical properties: These refer to physical attributes of materials that can be measured or observed without changing the composition of materials. They include porosity/permeability, surface, density, thermal conductivity and wear and tear.

Building code: This refers to a document created/drafted by a government to control or act as a standard for which all activities and specifications within the industry have to be met.

Content/Procedures/Methods/Illustrations

2.1 Physical properties of construction materials

Porosity

It is the measure of void spaces within the composition of a material and forms the basis of telling how permeable material is (permeable-ease with which fluids percolate through the voids of a material). It majorly affects materials such a masonry blocks and bricks among others. It can be determined by checking the weight change of a material after it has been submerged in water for a specific period of time by a structural engineer or experienced masons. It affects the choice of the place where the material will be used whether indoors or as an external material.

Surface texture

- It refers to the overall appearance of a material in its natural form and varies from smooth to rough.
- It is necessary as it influences additional activities that are required for it to perform its intended purpose and appearance.
- It is mostly decided by the client and architect based on the desired appearance.
- Its value is internationally determined but also subject to local trading laws and desired profit margins by manufacturers.

Strength

- It refers to the ability of a material to bear an applied force without failure or deformation.
- The desired strength of building material is determined by a structural engineer before construction during the design stage when calculating the loading.
- It majorly affects loads bearing materials like columns and beams (concrete and steel reinforcement) among others.
- It's the measure that determines structural soundness.
- It's determined by calculating comprehensive strength.

An important strength calculation in buildings is that of steel and it's done through the formula

$$Compressive\ strength = Force \div Area.$$

$$CS = F \div A$$

Density

It refers to the mass per unit volume of a material. Knowledge of density is important as it provides necessary information for the distribution of loads for structural purposes.
It's calculated by the formula.

$$Density = Mass \div Volume$$

It's mostly relevant to the structural engineer.

2.2 Chemical properties of construction materials

Corrosion resistance

Corrosion refers to a process through which metallic materials change into more stable compound namely oxides, sulfides and hydroxides in a natural gradual destruction process due to exposure to elements. Corrosion-resistance refers to how well a material can withstand damage from exposure to elements such as moisture and wind. It's determined by carrying out experiments in controlled environments by manufacturers. It majorly affects reinforcement window and door frames and roofing materials.

Chemical resistance

It refers to the strength of a material to withstand changes from interaction with other chemicals or solvents. It majorly affects the choice of paints and construction adhesives. It's measured and rated by manufactures with consideration made to the ISO standards. It is necessary as it aims products that have zero to minimal effect on the people using the spaces the materials are used. This is rather important when choosing materials for internal finishes as use of toxic substances cannot be allowed in (reader's digest, 2020) (reader's digest, 2020)living spaces. This is rather important when choosing materials for internal finishes as toxic substances cannot be allowed in living spaces.

2.3 Mechanical properties of construction materials

Toughness:

It refers to a material strength to understand adverse conditions or rough handling.
It is necessary as fragile materials are handled with care while tough ones can even be left exposed to the elements. The degree of toughness also affects the location and mode of storage as well as when they would be ordered, purchased and delivered on-site. Manufactures normally outline their materials degree of toughness and how to install and handle them. It's necessary as it enables professionals to avoid loses due to poor handling and installation.

Hardness

It refers to the comparative resistance of a mineral to scratching or the ability of a material to resist deformation, indentation or penetration by means such an abrasion, drilling, impact and wear measure in Mohs hardness scale. It's important as it affects the workability of materials.

Fatigue

It refers to the weakening of material in a progressive and localized manner caused by repeating application of load. In structures, damage occurs when the materials experienced stress range is considerably higher than material rating. It is calculated by manufactures who then produce products with different ranges. On-site cracking of members shows that there is fatigue.

Strain, stress, creep and stress rupture

These are forces that affect materials.

- **Strain:** Occurs as a result of tensional forces along the long axis.
- **Stress**: It refers to force per unit area that a material experiences which can be tensile or compressive majorly external forces.
- **Creep**: Refers to the tendency of a solid material to slowly change in position or deform when exposed to long term forces.
- **Stress rapture:** Its sudden and complete failure of a material under stress.

The impact of forces on materials is carried out by manufacturers and structural engineers refer to their standards in designing. As the spectrum of ranges is rather varied it is necessary to conform to standards.

Conclusion

This learning outcome covered physical properties of construction materials, chemical properties of construction materials, mechanical properties of construction materials engineering drawings interpretation, bills of quantities and construction materials.

Further Reading

From the internet read more on:

1. Properties of manufactured products/ engineered materials
2. Special materials such as rubber.
3. ISO standards

5.3.3.3 Self-Assessment

Written Assessment

1. Which of the followings, not a construction material property?
    a) Surface texture
    b) Density
    c) Corrosion
    d) Hardness
2. Which of the following properties is necessary when choosing a waterproof material?
    a) Density
    b) Surface texture
    c) Fatigue
    d) Hardness
3. Which of the below is not a physical construction material property.
    a) Thermal conductivity
    b) Wear and tear
    c) Strength
    d) Corrosion resistance
4. When a material undergoes permanent deformation, we say it has undergone? I.e. (over a long period of time gradually)
    a) Stress
    b) Creep
    c) Strain
    d) Stretch
5. Who is in charge of calculating the strength of building materials?
    a) Construction manager
    b) Structural engineer
    c) Client
    d) Architect
6. Why is calculating of forces necessary?
    a) To avoid fatigue
    b) To cut on cost
    c) To enhance the construction rate
    d) To produce quality.
7. What does porosity affect?
    a) Permeability
    b) Toughness
    c) Fatigue
    d) Hardness

8. Analyse permeability in reference to selection of Building materials.
9. Name two factors that affect the strength of building materials.
10. Summarise chemical properties that affect strength of materials during construction.
11. The mechanical properties of materials affect the strength of the material. As an architect, justify.
12. Evaluate ways in which the toughness of a material affects its handling and storage?

Oral assessment

1. John has been advised to buy bricks to build a 5-storey building. Compose a report outlining the advantages and physical properties of Brick.
2. State two mechanical properties of materials.

Practical Assessment

With reference to this learning outcome, carry out a project within a period of a weeks. Collect 5 samples of building materials and produce a properties document for presentation.

5.3.3.4 Tools, Equipment, Supplies and Materials

- Calculators.
- A computer for research/ smartphones

5.3.3.5 References

Adam, S., Ogier, J. M., Cariou, C., Mullot, R., Labiche, J., & Gardes, J. (2000). Symbol and character recognition: Application to engineering drawings. International Journal on Document Analysis and Recognition, 3(2), 89-101.

Chang, S. Y., Al Bahar, S. K., & Zhao, J. (2012). Advances in Civil Engineering and Building Materials. CRC Press.

Pacheco-Torgal, F., Jalali, S., & Fucci, A. (Eds.). (2012). Toxicity of building materials. Elsevier.

5.3.4 Learning Outcome No 3: Manufacturing Construction materials

5.3.4.1 Learning Activities

Learning Outcome No 3: Manufacturing construction materials	
Learning Activities	**Special Instructions**
3.1. Identify raw materials 3.2. Manufacture construction materials	• Demonstration • Use of charts • Field trips

5.3.2.2 Information Sheet No5/LO3: Manufacturing construction materials

Introduction

This learning outcome covers identifying raw materials based on construction materials to be produced and manufacturing construction materials as per manufacturing procedures.

Definition of key terms

Raw materials: Raw materials are substances or materials used in the initial manufacturing and production of materials.

Concrete: It is a material comprising a mixture of aggregate and cement or asphalt.

Content/Procedures/Methods/Illustrations

3.1. Raw materials are identified based on construction materials to be produced

There are three main types of construction materials in Kenya:

- **Cement:** Primary raw materials are limestone (supplies the lime in bulk) and clay, marl or shale (supplies the silica, alumina and ferric oxide in bulk). Other supplementary materials such as fly ash / pulverised fuel ash (PFA), sand or ironstone to achieve the desired bulk.
- **Brick: T**he raw material is clay.
- **Concrete**: The raw materials are fine and coarse aggregate, water and cement.

3.2 Construction materials are manufactured as per manufacturing procedures

Cement: Cement manufacturing is a complex procedure that begins with mining and grinding raw materials which include clay and limestone, to a fine powder known as raw meal, which is then heated to a sintering temperature as high as 1450^0c in a cement kiln. In this process, the chemical bonds of the raw materials are broken down and recombined into new compounds which are known as clinker, which are rounded nodules between 1mm and 2.5mm across. Clinker is ground to a fine powder in a cement mill and mixed with gypsum to create cement. The powdered cement is then mixed in water and aggregates to form the concrete that is used in construction.

Clinker quality depends on raw materials composition, which has to be closely monitored to ensure cement quality.

Concrete

The main concrete manufacturing process is as follows

- Batching
- Mixing
- Transporting
- Placing
- Compacting
- Curing

Batching: This is a major stage in the manufacturing of concrete. There is a measuring of materials (raw materials) such as aggregates, cement and water necessary for the preparation of different grades.

There are two processes:

- The volume batching is by mixing volume of the materials.
- The weight batching is by mixing materials with its volume. it has a ratio according to standard codes such as M10, M20, M25, and M30 for concrete

Mixing: This is done to produce high quality and uniform concrete. Separate paste mix shows the mixing of water and cement into a paste then combines with aggregates. This increase the compressive strength of concrete. This mix of paste in shear-type mixer is at high speed with 0.30 to 0.45 water-cement ratio. Aggregates are blended with premix paste. The remaining batch final and water mix complete in a rotating concrete mixing equipment.

Transporting - After mixing, it should be transported on the site with great care. The concrete transporting by trucks reach the construction site early and are more efficient.

Placing: In a good manner without segregation to reach maximum efficiency. The height depends on the separation of cement paste and aggregates; the higher the height the more probability of separation. Segregation of concrete causes honeycomb.
Compacting: Is the process which expels air trapped from freshly placed concrete and packs the particles together to increase the density of the concrete.

Curing: This is done to provide the best hardness and strength to concrete which helps the concrete to gain strength. It prevents cracking at the surface and avoids freezing and overheating of concrete.

Flow chart for manufacturing concrete

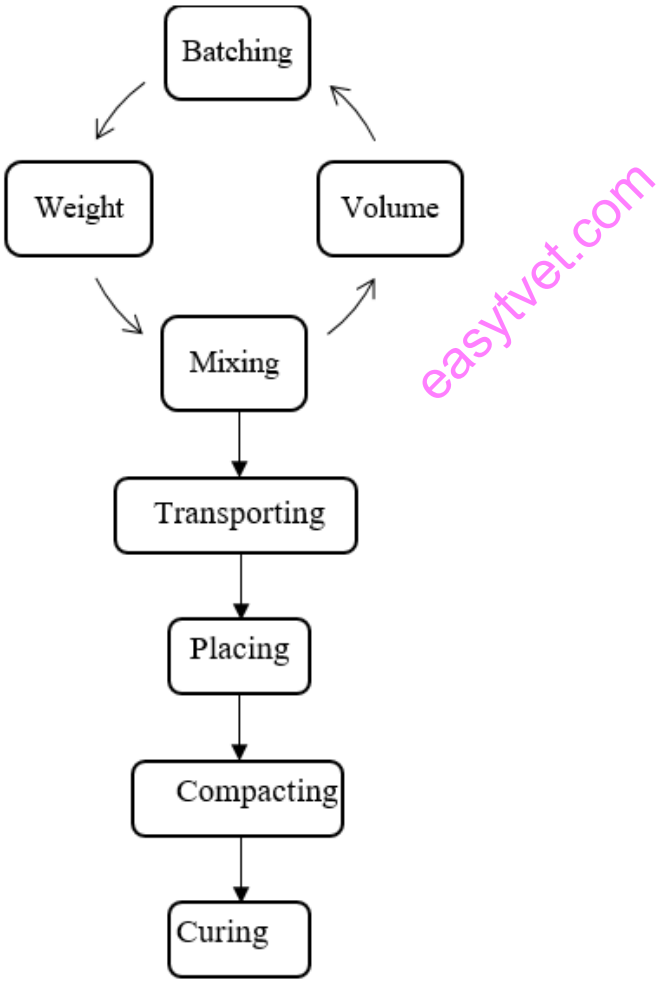

Figure 75: Flow chart for manufacturing concrete

Brick

There are four main different operations are involved.

- Preparation of clay
- Moulding
- Drying
- Burning

a) Preparation of clay

It is done in six steps:

i. **Unfailing of clay-** Pure clay is needed, the top layer of soil contains impurities, therefore, 200mm depth of clay is thrown away
ii. **Digging**- Clay is dug out from the ground and spread on the plain ground
iii. **Cleaning**- is the removal of stones and vegetable matter, then it is washed and cleaned.
iv. **Weathering**- The clean clay is exposed to the atmosphere for softening. The period maybe 3-4 weeks.
v. **Blending**- Addition of any ingredient to the clay by making the clay loose and spreading the ingredients over it.
vi. **Tempering**- Addition of water to clay and mixing or pressing. The pressing is done by cattle or men according to the scale of the project.

b) Moulding of clay

The prepared clay is moulded into a brick shape. It can be done in two ways (according to the scale of the project)

- Hand moulding for small scale
- Machine moulding for large scale

c) Drying of raw bricks

It is done otherwise they may be cracked while burning. The process is done naturally. Therefore, it is to remove moisture from the bricks.

d) Burning of brick

The dried bricks are burned either in kilns (for large scale) or clamps (for small scale) up to a certain temperature. The required temperature required for burning is about 1100^0c. this stage, the bricks gain hardness and strength as require.

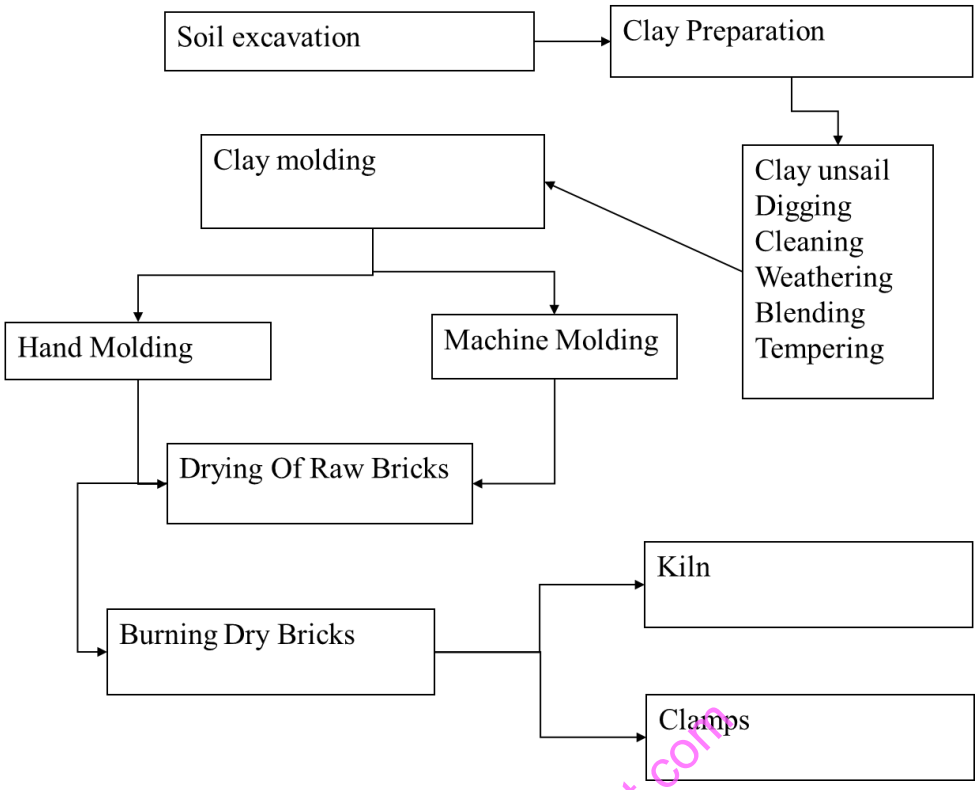

Figure 76: Flowchart for manufacturing brick

Conclusion

The learning outcome covered identifying raw materials based on construction materials to be produced and manufacturing construction materials as per manufacturing procedures.

Further Reading

1. Building Materials by S.S Bhavikatti
2. Building Materials by S.K Duggal
3. Fundamentals of Building Construction by Edward Allen

5.3.4.3 Self-Assessment

Written Assessment

1. Which process stage is not in the manufacturing of concrete?
    a) Compacting
    b) Burning
    c) Batching
    d) Curing

2. How many degrees are needed in burning during the manufacturing of bricks?
    a) 1100^0c
    b) 1500^0c
    c) 650^0c
    d) 900^0c
3. Which is the supplementary material information of cement?
    a) Water
    b) Clay
    c) Limestone
    d) Fly ash
4. Which batching ratio is not according to standard code?
    a) M10
    b) M25
    c) M40
    d) M30
5. What is the purpose of compacting in concrete manufacturing?
    a) To remove impurities for the concrete
    b) To strength the concrete
    c) To make the concrete durable
    d) To remove entrapped air from the concrete
6. Which one is not a stage in preparation of clay?
    a) Digging
    b) Moulding
    c) Weathering
    d) Blending
7. What determines the type of moulding will be done?
    a) The scale of the project
    b) The number of raw materials
    c) Time of the year
    d) The workmanship of the workers
8. Demonstrate batching of different types of materials.
9. Briefly discuss the main stages in concrete manufacturing.

Oral Assessment

1. Demonstrate the process of manufacturing of bricks?
2. Identify the raw materials used in cement, concrete and brick respectively?
3. Outline the procedure for preparing concrete

Practical Assessment

In groups of five with the aid of teacher bake ten bricks in the school workshop.

5.3.4.4 Tools, Equipment, Supplies and Materials

- Computer
- Labouratory testing equipment
- Labouratory apparatus
- Hand tools
- Machine tools

5.3.4.5 References

Cachim, P. B. (2009). Mechanical properties of brick aggregate concrete. Construction and Building Materials, 23(3), 1292-1297.

Rajgor, M., & Pitroda, J. (2013). Stone Sludge: Economical solution for the manufacturing of bricks. International journal of innovative technology and exploring engineering, 2(5), 16-20.

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5.3.5 Learning Outcome No 4: Selecting Quality Construction Materials

5.3.5.1 Learning Activities

Learning Outcome No 4: Selecting Quality Construction Materials	
Learning Activities	**Special Instructions**
4.1. Evaluate and analyse cost implications of construction materials 4.2. Select quality construction materials	• Written tests • Oral • Practical tests/Project

5.3.5.2 Information Sheet No4/LO4: Selecting Quality Construction Materials

Introduction

This learning outcome covers evaluating and analysing cost implications of construction materials and selecting quality construction materials based on their costs and project requirements.

Definition of key terms

Cost implications: This refers to the technique used to derive the duration, cost and energy required to manufacture and maintain construction materials.

Quality of construction material: This is the stability, durability and cost-efficiency of construction material.

Content/Procedures/Methods/Illustrations

4.1. Cost implications of construction materials are evaluated and analysed

The cost implication of construction materials involves analysis of time, money and energy required to efficiently produce and maintain building materials. Currently, the construction industry is one of the fastest-growing sectors of any economy, be it in developed countries or developing ones. The urge to deliver the best product output in terms of a well-designed building project, which is able to satisfy the client's needs and ultimate users cannot be emphasized (Safiki. A, Solikim. M, Nursahid. M, 2015). This can also be expressed by the value of money i.e. having to incur costs that cannot be dealt with. It is essential to calculate the most likely cost of a project to check if the project will be able to start and finally be successful. As an architect, you have to balance the need to maintain adequate internal control of a project while still constraining the construction budget. This is done to satisfy the needs of the client according to his/her budget. To do this, an effective control system is vital to making sure that long- term investment goals are achievable.

There are two types of cost implications that affect construction materials i.e. direct and indirect cost implications.

a) Direct cost implications

This focuses on how building strategies can affect the annual budget of a project. For instance, hiring additional casual labourers to a site to increase the rate of construction/manufacturing building materials might be too expensive for small firms/construction companies. Therefore, the number of casual labourers are decreased to increase the rate of affordability. This also improves, the quality of production improves due to efficiency in quality check.

b) Indirect cost implications

Efficiency in operations and productivity can be affected by the indirect cost of a project. For instance, managing manual cash in a site through verification of transactions e.g. purchase of steel, cement or stone; payment authorization from the lead consultant/contractor; and account reconciliation procedures between the parties. All these might lower efficiency resulting in wastage of time in production resulting in fewer products.

A change to the work or design as per the contract will incur additional charges that will, in turn, increase the cost of construction. This can occur through time lag between completion of designs and the time the project is to start depending on client's finance. As a result, friction between the client and contractor can result to cost overrun. If this is not solved, then the project might end up being abandoned. To control the variations in a project, the architect ensures that the variations are valid. I.e. they exist in writing, signed by the lead consultant, and finally submitted to registered offices for approval purposes.

4.2. Quality construction materials are selected based on their costs and project requirements

Materials will determine the aesthetics of your design or building. By ensuring high-quality materials, the level of workmanship is assumed to be of high quality. The factors that promote material and process selection include; the number of elements to be constructed, the size of elements, weight of the component and the precision required to satisfy the needs of the client. In terms of material, evaluation of material selection focuses on the ability of the material to be manufactured and processed into a finished structure. For instance, how easily can steel be cut on-site as compared to the manufacturing company?
Also, the sustainability of the products i.e. whether or not the materials manufactured can be reused for a different purpose as compared to what it is designed for. The quality of materials is determined by defect-free, the surface finish, dimensional accuracy and tolerance from external factors. From this, one can establish economic considerations which include, the cost to be considered, the quantity according to the volume of commodity and the rate of production of the commodity.

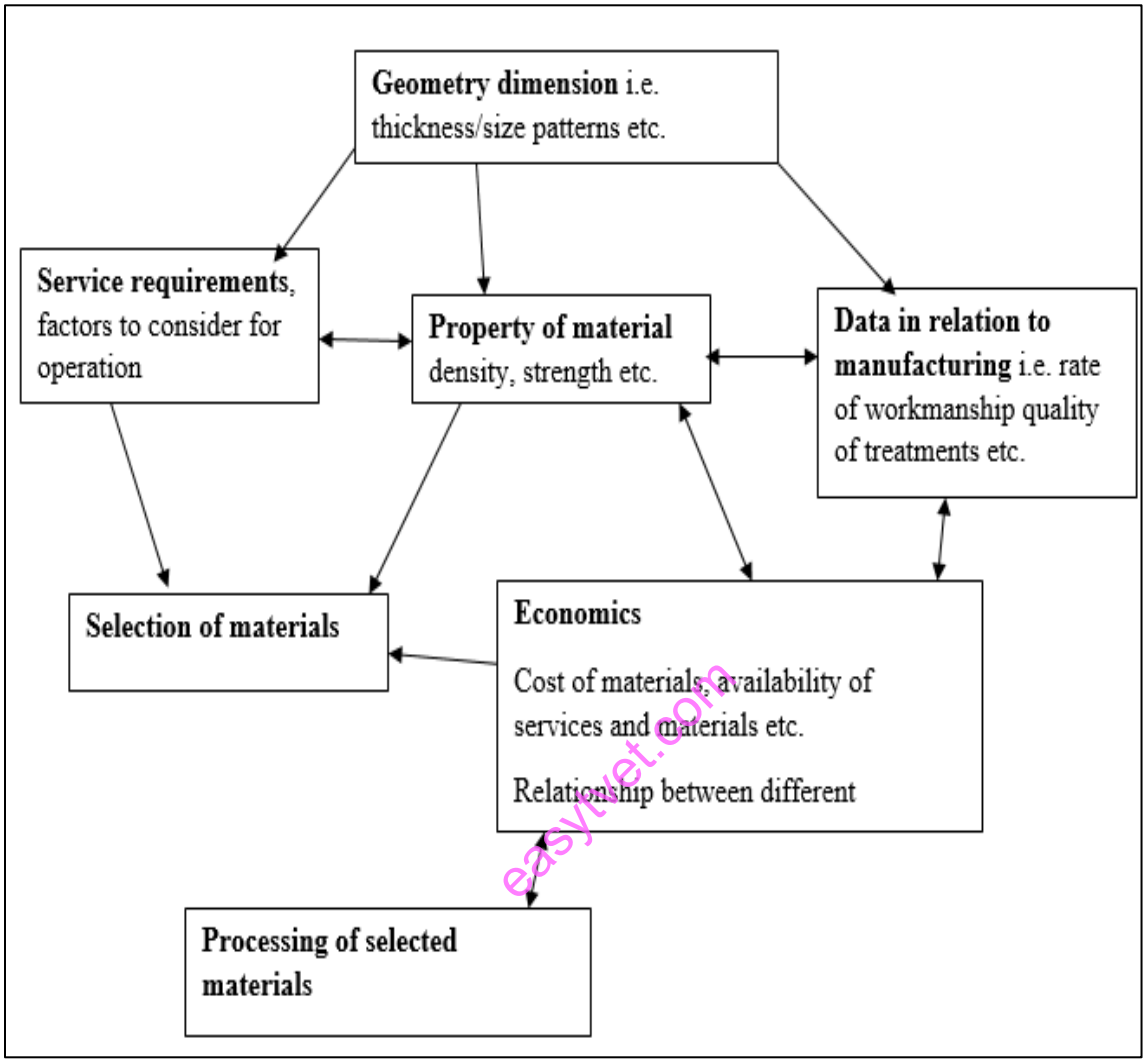

Figure 77: Quality construction materials selection

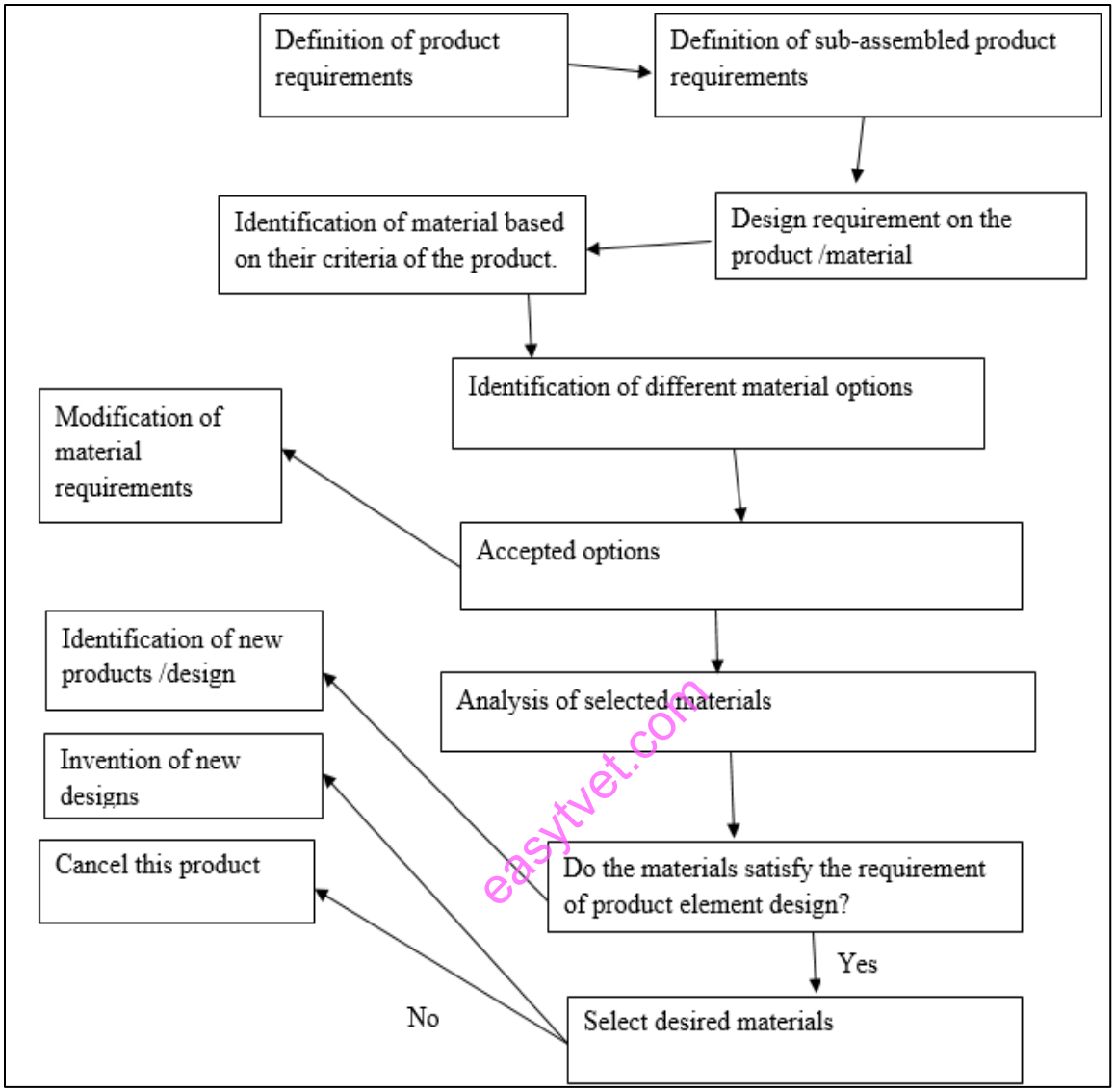

Figure 78**:** Process of material selection

Conclusion

The learning outcome covered evaluating and analyzing cost implications of construction materials and selecting quality construction materials based on their costs and project requirements.

Further Reading

1. Read further on cost implications and its effect on the built environment.
2. Read further on the selection of materials in relation to quality, availability and cost.

5.3.5.3 Self-Assessment

Written Assessment

1. Who of the following is in charge of ensuring variations are in the contract?
    a) Contractor
    b) Architect
    c) Clients
    d) Structural engineer
2. Why should cost implications be derived?
    a) To produce sustainable materials
    b) To derive solutions to construction
    c) To supply goods efficiency
    d) To efficiently connect pre-fabricated materials.
3. Which of the below is not a factor that promotes material and process selection?
    a) Size of materials
    b) Process of materials
    c) Weight of materials
    d) Number of materials
4. Identify the type of cost implication from the following?
    a) Cost implication variable
    b) Material cost implication
    c) Direct cost implication
    d) Serviceability cost implication
5. How can a building strategy affect the annual budget?
    a) Following the contract variable
    b) Addition of construction material
    c) Reduction of time for a project
    d) Employing additional casual labourers
6. Which activity is material selection in design associated with?
    a) Technical design
    b) Manufacturing
    c) The efficiency of the product
    d) Processing.
7. What factor describes the quality of the product?
    a) Availability
    b) Location of production
    c) Freedom from defects
    d) Ease of use

8. Justify the quality of construction materials used in building wood houses.
9. Evaluate freedom from defects?
10. Summarize the process of determining the quality of workmanship?
11. Briefly describe the process planning?
12. Justify material experience?

Oral Assessment

1. Propose the strategy will you use to ensure efficient cost analysis.
2. Evaluate material selection in reference to Construction.

Case study

Dunhill towers, Nairobi constructed a skyscraper using masonry concrete and steel. With references, produce a cost-benefit analysis and cost implications of the project.

5.3.5.4 Tools, Equipment, Supplies and Materials

- Computer
- Labouratory testing equipment
- Labouratory apparatus
- Hand tools
- Machine tools

5.3.5.5 References

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Science Direct (2020). Material Selection Process. Retrieval from Htpp//Ww.Sciencedirect.Com/Topics Engineering/ Material Selection Process

5.3.6 Learning Outcome No 5: Using Construction Materials Appropriately

5.3.6.1 Learning Activities

Learning Outcome No 5: Using Construction Materials Appropriately	
Learning Activities	**Special Instructions**
5.1. Assemble construction materials, tools and equipment 5.2. Use Construction materials depending on the construction process	• Demonstration • Oral assessment • Written assessment

5.3.6.2 Information Sheet No4/LO5: Using Construction Materials Appropriately

Introduction

In this learning, outcome covers assembling construction materials, tools and equipment based on the construction method and using construction materials based on the construction process.

Definition of key terms

Construction tools: This is any manufactured product component or equipment that is used in the construction process

Construction equipment: This is a variety of heavy-duty vehicles, tools and machinery which are capable of withstanding the harsh conditions experienced throughout the construction site.

Construction methods: These are the procedures and techniques that are used during the building process.

Building: It is the relatively permanent enclosed construction over a plot of land, having roof, windows doors often have a different use such as living, entertainment, manufacturing or residential.

Content/Procedures/Methods/Illustrations

5.1. Construction materials, tools and equipment are assembled based on construction methods

In order to come up with a structurally strong building and completion of a construction project, appropriate use of materials is one of the key elements. Use of materials majorly determined by the use of the building which includes the following:

- Residential building
- Education
- Assembly
- Storage
- Infrastructure
- Institutional
- Commercial

Construction materials

This is any manufactured product compound or equipment that is useful in the construction process. The most common materials used are:

- Stone
- Brick
- Lime
- Cement
- Concrete

a) Stone

Use of stone

- **Structure**- stones are used for foundation walls, columns, lintels, arches, roofs, floors, damp proof.
- **Aesthetic**- stones are adapted to give the massive appearance to the structure wall of bricks and facing is done in stones of desired shades.
- **Paving stones**- these are used to cover the floor of buildings of various types such as residential commercial, industrial etc.
- **Basic material**- are disintegrated and converted to form a basic material for cement concrete forum of roads

b) Bricks

Bricks are obtained by moulding clay in rectangular blocks of uniform size and then by drying and burning them.

Properties of bricks as a construction material:

- Durability
- Colour
- Texture
- Size variation
- Compressive strength
- Absorption

Classification of Bricks

First-class brick (A-type)

Thoroughly burnt bricks are deep, red, or copper colour. The surface of these bricks is smooth and rectangular with sharp and straight edges and square corners.

It is used for painting, exposed face work in a masonry structure, flooring and reinforcement brickwork. The water absorption is about 12%- 15%.

Second class (B-Type)

They are supposed to have some of the requirements in 1st class though they have some cracks and distortions and have more absorption power of about 16%- 20%

They are used in important hidden masonry works and centring of reinforced brick structures.

Third class bricks (C-Type)

These are under burnt bricks. They are soft and light-coloured producing a dull sound when struck against each other. Their absorption power is about 25% of dry weight. They are used in building temporary structures.

Fourth class bricks (D-Type)

Fourth class bricks are over burnt and badly distorted in shape, size and are brittle in nature. Used in filling foundation and floors.

a) Concrete

The cement and water form a paste that hardens and bonds the aggregated together.

It composes of

- water
- Aggregate
- Chemical mixture
- Cement

Properties of concrete

- Concrete has a higher compressive strength.
- It is a corrosion-resistant material and atmospheric agent has no effect on it.
- It is more economical than steel.
- It forms hard surface cable for resisting abrasion.
- Concrete walls and floors slow the passage of heat moving through and reduce temperature swing.
- Being naturally five resistant concrete forms a highly effective barrier to five spread.

Reinforced cement concrete

Strong in compression as the aggregate efficiently carries the compression load. Weak in tension as the cement holding aggregate in place can crack allowing the structure to fail. Reinforced concrete solves these problems by adding either metal reinforcing bars, steel fibres, glass fibre, or plastic fibre to carry tensile loads.

Use

RCC is used as a structural member wherever bending of the member is required: Like in footing, columns, beams, lintels, and stairs.

d) Cement

The crystalline compound of calcium silicate and other calcium compounds having hydraulic properties.

Use.

- Main use in the fabrication of concrete and mortars.
- Building (floors, beams, columns, roofing, piles, brick, mortars, panels, plaster)
- Transport (roads, pathways, crossing bridges viaduct tunnels)
- Water (pipes, drains, canals, dams, banks, pools)
- Civil (piers, docks, retaining walls, silos, warehousing, poles, pylons, fencing)
- Agriculture (building, processing, house irrigation)

e) Limestone

Limestone is a sedimentary rock composed largely of the minerals calcite and aragonite which are different crystal forms of calcium carbonate (CaCO3).

Uses.

- It is the raw material for the manufacture of quicklime
- (Calcium oxide), slacked lime (calcium hydroxide) cement and mortar.
- It is crushed for use as aggregate- the solid base for many roads.

Construction Equipment

This is a variety of heavy-duty vehicles, tools and machinery which are capable of withstanding the harsh conditions experienced throughout the construction site.

Criteria to select construction equipment

The type, size and other particulars of equipment. Whether the equipment is to be purchased, rented or to be procured hire-cum-purchase arrangement.

Advantages

- Increase the rate of output through work progress with the best effective and efficient methods.
- Reduce overall construction cost especially for large contracts.
- Carry out activities which cannot be done manually or to do them more economically and much faster.
- Eliminate the heavy manual work by human thus reducing fatigue and eliminates various other hazards and health issues.
- Maintain the planned rate of production where there is a shortage of skilled or unskilled labour.

Disadvantages

- If the machine breaks down, it can cause delay of construction work.
- Electric tools can cause a short circuit which may result to fire.
- Only skilled labour can operate the equipment.
- Special assistance is required to operate them as it may harm people on the site.
- Contractors in small projects create an issue over buying or rating of equipment and may charge high charges.

Types of Equipment

- Electric hand tools
- Vibrators
- Pumps
- Compactors
- Rollers
- Concrete mixers
- Hand pumps for ready-mix- concrete
- Transport equipment

Electric Hand Tools

A power tool is an instrument that is actuated by an additional power source and mechanism other than the solely manual labour uses with hand tools.

They include:

- Saws
- Drills
- Polishers
- Plate compactors
- Concrete vibrators
- Electric drivers
- Ceramic file cutter
- Jackhammer

5.1. Assembling construction materials, tools and equipment based on the construction method.

Procedure

i. Site clearing

This is the removal of vegetation and topsoil from the site.
For this, you assemble equipment such as
Bulldozers, excavators and graders for a large project but for small projects normal digging with jembes are recommended.

ii. Foundation

This is the structure in a building that transmits building load to the ground and holds the building firmly into the soil.
For this, it requires the use of the following materials:

- Steel (for reinforcement)
- Cement(adhesive)
- Concrete (structural strength)
- Scaffolding (to hold the concrete in place)

Assembled equipment include:

- Concrete mixers
- Vibrator

iii. Superstructure

This includes partitions, beams and columns.
For this process the following materials are assembled:

- Stone (masonry) used as a partition.
- Cement (Adhesive) to bind stone together.
- Concrete (for the making of columns and beams)
- Steel (Reinforcement in the concrete)

The beams and columns are laid out with the use of moulds. They are left to cure as water is poured. Masonry stone is laid out to create partitions according to the drawings.

iv. Roofing.

This is the top covering of the structure. The following materials are assembled:

- Iron sheets or roofing tiles which are the topmost covering of a house.
- Wood- laid out as a skeleton to hold the iron sheets in place.
- Nails- to hold the wood to the iron sheets.

5.2. Construction materials are used based on the construction process

Construction process

a) Foundation

The building site is graded and excavated and the boundaries of the foundation are laid out before the basic plumbing is installed the foundation is poured. The clearing of the site is done with equipment such as excavator and Levelized by graders. The foundation to be poured is majorly concrete on top of the stones used for pack filling of the foundation trenches.

b) Framing

The interior and exterior walls are installed. The wall is made of masonry stone from the quarry or machine cut stone, they are joined together using cement. In other places such as the exterior wall back is used for aesthetic purposes.

c) Plumbing, mechanical and electrical configuration

A host of installation occurs during this phase as the water and wastewater piping is installed along with the electrical wiring, ducting HVAC system and water heater.

d) Insulation and drywall installation

The walls are insulated and then the drywall is installed over the walls. At this stage, you'll be able to see your vision start taking form.

e) Exterior and interior

The final touches are made to the construction project. All remaining electrical mechanical HVAC and plumbing system are installed and the ceiling, doors, window sills, cabinets, tiles, countertops, mirrors, light and other fixtures are finalized. If a driveway is involved. It's at this stage that it is completed along with the sidewalk modification and landscaping can begin for your garden and footpath.

Conclusion

The learning outcome covered assembling construction materials, tools and equipment based on construction methods and, using construction materials based on the construction process.

5.3.6.3 Self-Assessment

Written Assessment

1. What do you understand by the word construction material?
    a) An instrument used in construction.
    b) The powder used as an adhesive in building
    c) Any manufactured product component or equipment that is used in the construction process.
2. Which of the following is construction equipment?
    a) Spade
    b) Excavator
    c) Spoon
3. The tool used to drive a nail in a piece of wood is called?
    a) Hummer
    b) Cement
    c) Sand
4. Which material is most appropriate for the making of foundation?
    a) Concrete
    b) Reinforced concrete
    c) Sand
5. Justify the advantages of reinforced concrete over ballast.
6. Analyse the properties of bricks that make it an appropriate construction material.
7. As an architect, evaluate the advantages of State one advantage of construction equipment.
8. State one disadvantage of construction equipment.
9. Explain the construction process.

Oral Assessment

1. Define construction material
2. Outline construction materials are seen in any construction site you have visited

Practical Assessment

With the help of trained personnel use the following materials to come up with a foundation slab of measurements 1m×1m×0.5m

a) Cement
b) Ballast
c) Sand
d) Water
e) Steel reinforcement

5.3.6.4 Tools, Equipment, Supplies and Materials

- Computer
- Hand tools
- Machine tools
- Chats with the picture and names of construction equipment.
- Drawing books.
- Rulers and T- square

5.3.6.5 References

Francis D.K. Ching (2008) Building construction illustrated (New Jersey) John Wiley and Sons, Inc.

Frederick. S. Merrit (2000) Building Design and Construction Handbook (California) McGraw Hill

Roy Chudley (2014) Building Construction Handbook (London) Routledge

5.3.7 Learning Outcome No 6: Testing Construction Materials

5.3.7.1 Learning Activities

Learning Outcome No 6: Testing Construction Materials	
 **Learning Activities**	**Special Instructions**
6.1. Sample construction materials randomly 6.2. Identify **test parameters** 6.3. Test construction materials	• Trainer to conduct field trips • Conduct lab tests • Trainer to conduct field trips • Trainer to carry out demonstration

5.3.7.2 Information Sheet No5/LO6: Testing Construction Materials

Introduction

This learning outcome covers randomly sampling construction materials as per SOPs, identifying test parameters (compression, weathering, durability, water absorption, impurity test and tensile tests) as per the construction requirements and engineer's instructions and testing construction materials as per SOPs.

Definition of key terms

Impurity test: They are aimed at the identification and management of the presence of foreign substances in a material.

Weathering: Refers to decaying and decomposition of materials caused by physical or chemical agents

Test parameters: Refers to the various aspects of a material that can be subjected to tests

Content/Procedures/Methods/Illustrations

6.1. Construction materials are sampled randomly as per SOPs

Construction materials basically refer to manufactured and naturally occurring substance that may be used in the building of houses, bridges etc. The standard operating procedures (SOP's) govern matters such as quality of the construction materials and their compliance to regulations as per the zones where construction will take place. Sampling is generally conducted so as to allow for tests to be carried out on the construction materials.

Construction materials are samples based on quality availed for construction, extraction of material e.g. by manufacturing a natural occurrence and also by the construction process that would be required for certain construction material. Ideally, the most reliable method to ascertain the sample of the materials to be tested include the whole scope of a construction process by incorporating a stratified random sampling procedure into the sampling process to ensure a successful implementation of this divide the samples into a recommended number of equal groups in accordance with the standard. In the event that the groups are of an unequal size weighing the samples to ensure a reliable sampling process is necessary. For example, sampling for wood or timber construction materials may be conducted by selecting model trees in a test area and sticks specimen. The selection may be based on their girth. The specimen selected shall be clear and straight, free from decomposition and protection from moisture and weather is necessary.

6.2. Test parameters (compression, weathering, durability, water absorption, impurity test and tensile tests) are identified as per the construction requirements and engineer's instructions.

Test parameters refer to the characteristics or qualities of a material to be used in construction that can and should be subjected to tests since the various qualities would affect the quality of a construction project if they go unchecked. The parameters may include the strength of a material, climatic compliance of a material i.e. how the material is affected by different climates for example rains or too much heat, maintenance demand, water absorption capabilities of a material, impurity content etc. The need for identification of these parameters is to ensure productivity and efficiency of building materials. Identification of these parameters helps to keep within the originally approved budgets since identified parameters are addressed during testing and budgeted, improve the quality of building and infrastructure. The most desirable parameters to be considered for a choice of a building material include:

- **Ease of installation**

The ease or complications of installing a material may, in the long run, affect the budget thus consideration should be put on how easy it is to install the material.

- **Durability**

The construction materials should be weather compliant so as to reduce the cost incurred in replacing a material that has been damaged by adverse weather conditions. Tests should be conducted on the material to gain knowledge on the effects the weather will have on it.

- **Health safety**

The effects a certain building material will have on health need to be identified through tests. Different materials may have effects such as the release of pollutants by asbestos materials and fire management.

Tests on fire hazards such as ignitability, the spread of flame and fire resistance need to be carried out to ensure that the occupants can live safely from such hazards. Harmful effects can be contained by limiting the use of substances that contain harmful solvents, provision of good ventilation and following manufacturer's recommendations (Daily monitor, 2007).

- **Test for compression**

This is where variables such as strain and deformation are measured in a material by determining its response to compressive load. This helps to determine the materials elastic limit, yield strength etc. therefore determining the suitability of the materials for a purpose.

- **Test for weathering**

This is a test to determine how the material is affected by different weather elements and the rate to which elements can be exposed e.g. for roofing materials and which need to be protected from weather elements.

- **Test for water absorption**

This test determines the coarse and fine aggregates water holding capacity. The purpose of this test is to measure the strength and quality of the material.

- **Impurity test**

This is a test to enable realization and control of foreign substances in a material that would compromise the materials structural integrity.

- **Tensile tests**

This test is usually done by measuring the force required to elongate the test material to its breaking point. This helps professionals determine how materials will behave in their intended applications.

6.3. Construction materials are tested as per the SOPs

Testing of construction materials basically refers to the procedures intended to establish the quality and the reliability of structural materials that would be used to build projects from foundations to roof. The tests to be carried may be physical, chemical, verification of quantity and checking for damage.

Construction materials are tested for the purpose of:

- **Complying with regulatory requirements**

The government of every particular state or regulatory bodies have a set standard to be met by manufacturers of every material. This helps to restrict the manufacturing of substandard or hazardous materials.

- **Material and treatment selection**

Testing of the materials enables one to understand and determine whether certain material or treatment is suitable for a specified application

Product design and improvement

Testing quantifies the strength, hardness, elasticity etc. of a structure. Testing, therefore, helps to determine the most appropriate design that will hold up at a particular site. Materials tested may include soils and aggregates which are tested during excavation activities, asphalt, concrete, masonry etc. are tested to ensure that the specified conditions meet the acceptable criteria specified.

Destructive tests on construction materials are used to understand a specimen's failure to learn how it behaves under different loads. Destructive tests destroy the specimen such that even if it passes the test it is no longer fit for service while non-destructive tests, the specimen can be used for service (TWT, 2017)

For example, the concrete slump test is as follows:

a) Put the mould for the slump test in a frustum
b) Put the base on a smooth surface and concrete-filled in three layers
c) When the mould is filled, the top surface is struck off
d) Carefully lift the cone vertically let the unsupported concrete slump.

Precaution for slump test: Inside of the mould and its base should be moistened.

Conclusion

The learning outcome has covered randomly sampling construction materials as per SOPs, identifying test parameters (compression, weathering, durability, water absorption, impurity test and tensile tests) as per the construction requirements and engineer's instructions and testing construction materials as per SOPs.

Further Reading

1. Read on other tests for concrete and soil
2. Read on ideal locations to carry out construction materials testing.

5.3.7.3 Self-Assessment

Written Assessment

1. The resistance of the soil with depth is measured by a tool called?
    a) Seismometer
    b) Ammeter
    c) Potentiometer
    d) Penetrometer
2. What is the average depth of a test pit?
    a) 10 M
    b) 2 M
    c) 1.5 M
    d) 15 M
3. Shocks that travel within the soil are measured by an instrument called?
    a) Microphone
    b) Geophone
    c) Receiver
    d) Sensors
4. Which of the following has more fire-resisting characteristics?
    a) Granite
    b) Compact sandstone
    c) Marble
    d) Limestone
5. Due to the effects of dry rot, the timber?
    a) Cracks
    b) Shrinks
    c) Reduces to powder
    d) None of these

6. For testing the compressive and tensile strength of cement, the cement mortar is made up by mixing and standard sand in properties of:
    a) 1: 2
    b) 1: 3
    c) 1: 4
    d) 1: 6
7. Clay and silt content in good brick earth must be at least?
    a) 50%
    b) 40%
    c) 30%
    d) 25%
8. Evaluate the uses of a retarder in concrete?
9. Iron ore has different levels of purity, Summaries.
10. Justify the use of Stretcher bonds in masonry.
11. Summarise the different types of rocks.
12. Distinguish the different effects of excess alumna on bricks.

Oral Assessment

1. Which material is used in binding mortar?
2. What is the content of carbon in wrought iron?

Practical Assessment

Carry out stratified random sampling to be used to sample timber

5.3.7.4 Tools, Equipment, Supplies and Materials

- Computer
- Labouratory testing equipment
- Labouratory apparatus
- Hand tools
- Machine tools

5.3.7.5 References

Foster (2007). Mechanical testing of metals and alloys. New York. Oxford university press

Heinemann (2006). Building construction handbook. Oxford Routledge publishers

Williams (2007). Increase in greenhouse emissions from projects. Washington. The sightline institute

5.3.8 Learning Outcome No 7: Handling Construction Materials Safely

5.3.8.1 Learning Activities

Learning Outcome No 7: Handling Construction Materials Safely	
 **Learning Activities**	**Special Instructions**
7.1. Identify construction materials 7.2. Identify Safety requirements 7.3. Safely handle construction materials	• Written tests • Oral • Practical tests/Project

4.3.8.2 Information Sheet No5/LO1: Handling Construction Materials Safely

Introduction to learning outcome

This learning outcome covers identifying construction materials to be handled, identifying safety requirements based on the construction materials and safely handling construction materials based on the safety requirements. Construction materials are materials used for construction purposes. Material handling is the movement, protection and storage of these materials. Therefore, handling and storing of construction materials involves diverse operations such as hoisting tons of steel with a crane, driving a truck loaded with concrete blocks carrying bags of materials manually; and stacking palletized bricks or other materials such as barrels and lumber.

Definition of key terms

Safety requirements: These requirements that are defined for purposes of risk reduction e.g. all-new powered industrial trucks except vehicles intended primarily for earth moving or the over the road hauling must meet the design and construction requirements for powered industrial trucks established in the American National Standard for Powered Industrial trucks, Part2, ANSI B56.1-1969

Safety measures: These are activities and precautions taken to improve safety on-site mainly to reduce the number of accidents associated with workplace equipment; employees in the proper use and limitations of the equipment they operate e.g. Proper use of cranes on site.

Material handling: This is the movement, protection and storage of construction materials on-site in a safe manner. For example, never lift a load over an obstacle and perform lifts in areas with adequate footing, space and lighting.

Content/Procedures/Methods/Illustrations

7.1. Construction materials

Construction materials refer to any materials used for construction purpose. They are materials used for house building. These include wood, cement, aggregates, metals, bricks, concrete, and clay. The choice of these materials is based on their cost-effectiveness for building projects.

Types of building materials used in construction

Wood

It is a product of trees, and sometimes other fibrous plants used for construction purpose when cutting or pressed into lumber and timber such as fiberboards and plants. It is a generic building material and is used in building about any type of structure in most climates. Wood can be very flexible under loads, keeping strength while bending and is incredibly strong when compressed vertically. Wood is also basically used and preferred in interior design because it is timeless in nature and does not increase in value.

Historically, wood for building large structures was used in its unprocessed form as logs. The trees were just cut to the needed length, sometimes stripped of bark and then notched or lashed into place. Currently with the invention of mechanizing saws came the mass production of dimensional lumber. This made buildings quicker to put up and more uniform, thus the modern western styles home was made.

Advantages of Dimensional Lumber (Glulam)

i. Size- one can get the very huge size of wood depending on how you glue the wood strips.
ii. Architectural freedom- the wood can span long distances past 6m and 8m e.g. In open spaces such as Amphitheaters.
iii. Quality of wood is good since the control processes of drying and bonding of the wood strips are done in the factory.
iv. There is the efficient use of lumber grades-there is minimum wastage of wood since wood is placed where it is needed most.
v. It is environmentally friendly.

Brick and Block

A brick is a block made of kiln-fired materials usually clay or shale but it also may be of lower quality mud etc.

Clay bricks are formed in moulding (the soft mud mothered) or in commercial manufacture more frequently by extruding clay through a die and then wire-cutting them to the proper size the stiff mud process). Bricks were widely used as a construction material in 1700, 1800 and 1900s. This was probably due to the fact that it was much more flame retardant than wood in the ever-crowding countries and fairly cheap to produce. Another type of block replaced clay bricks in the late 20^{th} century. It was the Cinderblocks made mostly from concrete. An important low-cost material in developing countries is the sand rete block which is weaker but cheaper than the fired clay bricks.

Concrete

Concrete is a composite building material made from the combination of aggregate (composite) and a binder such as cement. The most common form of concrete is Portland cement concrete which consists of mineral aggregate (generally gravel and sand) Portland cement and water. After mixing the cement hydrates and eventually hardens into a stone-like material. When used in the generic sense, this is the material referred to by the term concrete. For a concrete construction of any size, as concrete has a rather tensile strength, it is generally strengthened using steel rods or bars known as robes. This strengthened concrete is then referred to as reinforced concrete. In order to minimize any bubbles that would weaken the structure, a vibrator is used to eliminate any air that has been entrained when the liquid concrete mix is poured around the ironwork. Concrete has been the predominant material in this modern age due to its longevity, formability and ease of transport.

Metal

It is used as a structural framework for larger buildings such as skyscrapers or as an external surface covering. There are many types of metals used for building. Steel, for instance, is a metal alloy whose major component is iron and is the usual choice for metal structural construction. It is strong and flexible and if refined well and well treated last a long time. Corrosion is metals, prime enemy, when it comes to longevity. The lower density and better corrosion resistance of aluminium alloys and tin are sometimes overcome by their greater cost. Brass was more common in the past but it is usually restricted to specific uses or specialty items today. Other metals used include titanium, chrome, and gold, silver. Titanium can be used for structural purposes but is much more expensive than steel.

Glass

Clear windows have been used since the invention of glass to cover small openings in a building. They provided human with the ability to both let light into the rooms while at the same time keeping demand weather outside. Glass is generally made from mixtures of sand and silicates and is very brittle. Modern glass "curtain walls" can be used to cover the entire façade of a building.

Glass can also be used to span over a wide roof structure in a space frame.

Ceramics

They are such things such as tiles, fixtures etc. They are mostly used as fixtures or coverings in buildings. Ceramic floors, walls, countertops even ceilings. Many countries use ceramic roofing tiles to cover many buildings. Ceramics used to be just specialized form of clay pottery firing in kilns but it has evolved into more technical areas.

- **Plastics**

Plastics vary immensely in heat tolerance, hardness and resiliency. Combined with this adaptability, the general uniformity of composition and lightness of plastic ensures their use in almost all industrial applications today.

- **Brush**

Are built entirely from plant parts and are generally found in the tropics. These are mostly built with branches, twigs and leaves and bark similar to a beaver's top.

7.2. Safety requirements are identified based on the construction materials

Safety requirements are requirements that are purposefully set for risk reduction on a construction site. They include:

i. Scaffold must be sound, rigid and sufficient- to carry its own weight plus four times the maximum intended load without settling or displacement. It must be erected on solid footing.
ii. Employees should consider using aerial lifts or elevated platforms in a case where there are unstable working surfaces so as to provide safer elevated working surfaces.
iii. Provide or erect guardrail systems with tool boards and warning lines or install control line systems to protect workers near the edges of floors and roofs so as to prevent cases of fall.
iv. Ladders and stairways are other sources of injuries and fatalities among construction workers. Make sure there is the use of the correct ladder for the task and make sure the ladders are long enough to safely reach the work area.

v. Slips, trips and falls on stairways are a major source of injuries and fatalities among construction workers. Ensure stairways treads cover the entire step and landing. Ensure also that the stairways having four or more risers or rising more than 30 inches must have at least one hand drain.
vi. Sloping- maximum allowable slopes for excavations less than 20 feet (6.09M) based on the soil type and angle to the horizontal.
vii. Failure to recognize the hazards associated with chemicals can cause chemical burns, respiratory problems and fires and even explosions. Ensure that you maintain an MSDS (Material Safety Data Sheet) for each chemical in the facility.
viii. Serious head injuries as a result from blows to the head- ensure that the workers wear hard hats where there is potential for objects falling from above, bumps to their heads from fixed objects, or accidental head contact with electrical hazards.
ix. Trench collapsing injuries to the employees- ensure no employee enters an unprotected trench.
x. Existing energized (not) electrical circuits should be prohibited to avoid accidents.

7.3. Construction materials are handled safely based on the safety requirements

i. Do not place the construction materials within 6 feet of any hoistway or inside floor openings or within 10 feet of an exterior wall that does not extend above the top of the material sheet.
ii. Stack bagged materials by stepping back the layers and cross keying the bags at least every ten bags high.
iii. Do not stack brick more than 7 feet in height. When stacks of bricks reach 4 feet height, start tapering it back 2 inches for every foot of height above the 4-foot level.
iv. Masonry blocks typically stack easier than brick but when stacking masonry blocks higher than 6 feet, taper the stack back one-half blocks per tier above the 6-foot level.
v. For lumber stacked by machine, the piles cannot exceed 20 feet in height. Lumber that is going to be handled manually can't be stacked more than 16 feet high. For lumber storage;
    - Remove all used nails before stacking
    - Stack lumber on level and solidly supported sills
    - Stack lumber so it is stable and self- supporting
    - Do not store excess materials on the scaffolds' or runways. Keep only the amount needed for immediate operations.

Figure 79: Dimensional Lumber (GLUELAM) being dried up in a kiln drier.

Conclusion

The learning outcome has covered identifying construction materials to be handled, identifying safety requirements based on the construction materials and safely handling construction materials based on the safety requirements.

5.3.8.3 Self-Assessment

Written Assessment

1. Material handling consists of movement of material from
    a) One machine to another.
    b) One shop to another shop
    c) Stores to shop
    d) All of the above
2. Principle of “unit load” states that
    a) Materials should be moved in lots
    b) One unit should be moved at a time.
    c) Both a and b
    d) None of the above.
3. The economy in material handling can be achieved by
    a) Employing gravity food movements
    b) Minimizing the distance of travel
    c) By carrying material to destination without using manual labour
    d) All of the above.
4. The forklift truck is used for
    a) Lifting and lowering
    b) Vertical transportation
    c) Both A and B
    d) None of the above

5. Cranes are used for
    a) Lifting and lowering
    b) Vertical transportation
    c) Both a and b
    d) None of the above
6. Wheelbarrows are used for
    a) Lifting and lowering
    b) Vertical transportation
    c) Both A and B
    d) None of the above.
7. Which one of the following is not a construction material?
    a) Concrete
    b) Ceramics
    c) Wood.
    d) Bill of quantities
8. Mention three types of building materials in construction
9. What is the difference between safety requirements and material handling and storage?
10. Classify different safety measure to be observed while handling lumber as a building material.
11. Analyse safety requirements.
12. Develop a check list on the properties to consider while identifying materials.

Practical Assessment

Visit a potential construction site. Observe how the construction materials are being handled safely on site. Mix cement and sand aggregates using the concrete mixer in a clean and safe manner; using appropriate ratios of 1: 2

4.3.8.4 Tools, Equipment, Supplies and Materials

- Drawing books
- Reference books
- Set Squares
- T-squares

4.3.8.5 References

Code of Federal regulation. (2002) Concrete and Masonry construction.US OSHA
Code of Federal regulation. (2004) Control of Hazardous Energy. US. OSHA
Job Hazard Analysis. (2002) Personal Protective Equipment. The US.OSHA