CHAPTER 1: 1 BUILDING MATERIALS SCIENCE

Unit of learning code: UNIT CODE: CON/CU/BUT/CC/03/6

Related Unit of Competency in Occupational Standard: APPLY BUILDING MATERIALS SCIENCE

1.1 Introduction to the unit of learning

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.

1.1.1 Summary of Learning Outcomes

1. Identify essential construction materials
2. Identify properties of construction materials
3. Manufacture construction materials
4. Select quality construction materials
5. Use construction materials appropriately
6. Test construction materials
7. Handle construction materials safely

1.2.5 1.2.1 LEARNING OUTCOME 1: IDENTIFY ESSENTIAL CONSTRUCTION MATERIALS

1.2.1.1 Introduction to learning out come

This learning outcome specifies the content of competencies required to Identify essential construction materials. It includes; Engineering drawings interpretation, Bills of quantities, Construction materials.

1.2.1.2 Performance standard

1.1 Bills of quantities and working drawings are obtained and interpreted

1.2 Essential construction materials are identified based on construction

requirements and project's scope.

1.2.1.3 Information sheet

❖ *Terms and concepts*

a) Engineering drawings
b) Bill of quantities
c) Working drawings
d) Contingency sums
e) Tendering
f) Quantity surveyor
g) Valuation

a) Engineering drawings-

Type of technical drawing used to define the requirements for engineering products or components. Typically, the purpose of an engineering drawing is to clearly and accurately capture all geometric features of a product or component so that a manufacturer or engineer can produce the required item. It may also describe the process of making the item, may be used to convey engineering ideas during the design process, or may provide a record of an existing item.

Below are the basics concepts of Engineering Drawing:

- **Orthographic Views-**

two-dimensional views of objects where the viewpoint of the object is at right angles to surfaces. They are used in technical and engineering drawings for accuracy.

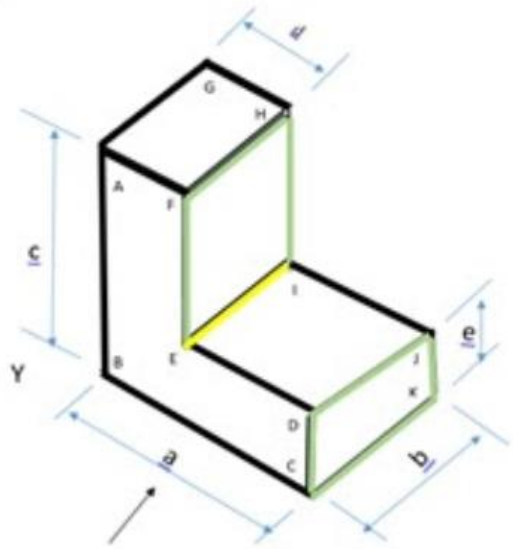

Figure 1 Pictorial view of object

https://learnengineeringdrawing.blogspot.com/2016/05/orthographic-projection-in-first-angle.html

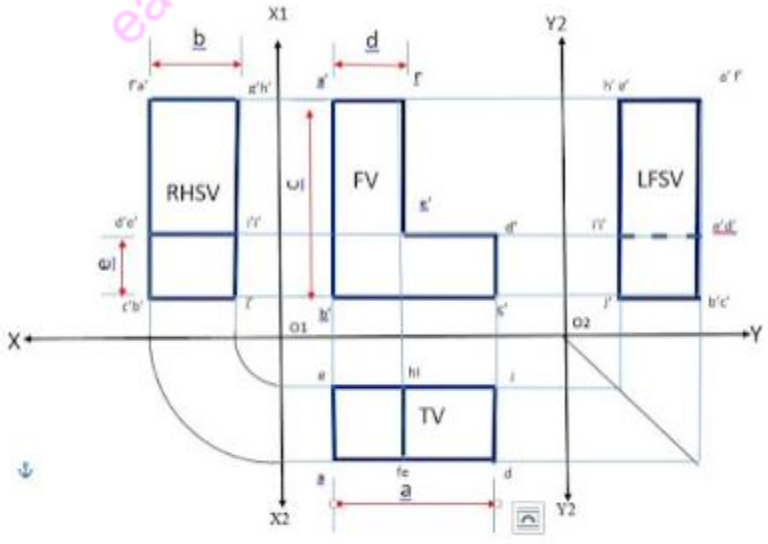

Figure 2 Orthographic projection of object in First angle of projection

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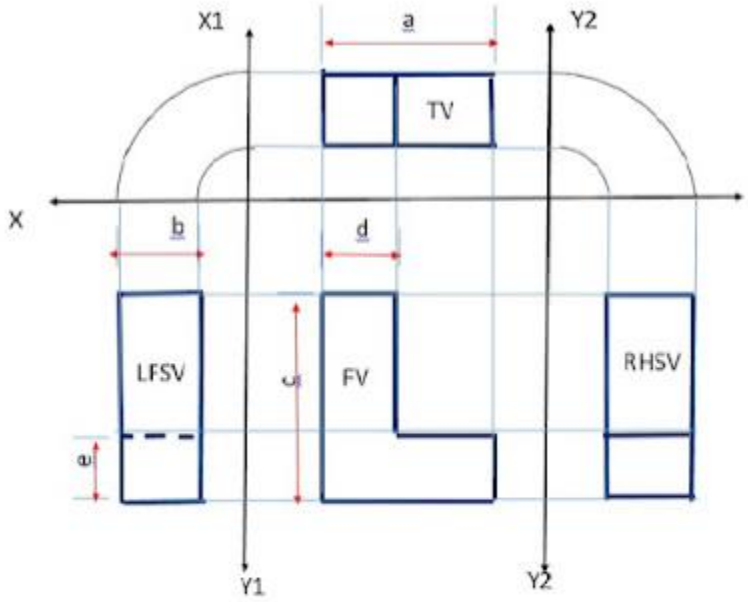


Figure 3 Orthographic projection of object in Third angle of projection

https://learnengineeringdrawing.blogspot.com/2016/05/orthographic-projection-in-first-angle.html

Types of Drawing Lines

- ***Object Lines:-***
  Depict the visible edges of an object. The edges you would see looking at the object with your naked eyes. They shown as dark, solid lines.
- ***Hidden lines:-***
  Depict invisible edges inside an object. The edges you would not see looking at the object with your naked eyes. They are shown as dashed lines.
- ***Center Lines:-***
  Depict the center of any cylindrical-shaped object whether it be a cylinder or hole. They are shown as a long line followed by a short line, followed by a long line

➢ ***Dimensions and Notes-***

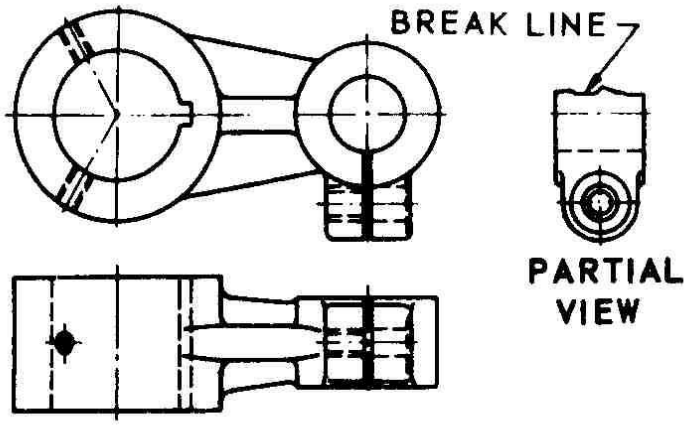
Tell how far it is from one point on an object to another point. The most basic type is called a ***Linear*** Dimension because it gives the straight-line distance from one

point to another. There are also ***Radial***, ***Diameter*** and ***Angular*** Dimensions. Dimensions have four basic components: (i) *Dimension Text,(ii) Dimension Line and Arrows,(iii) Extension Lines and (iv) Gap*

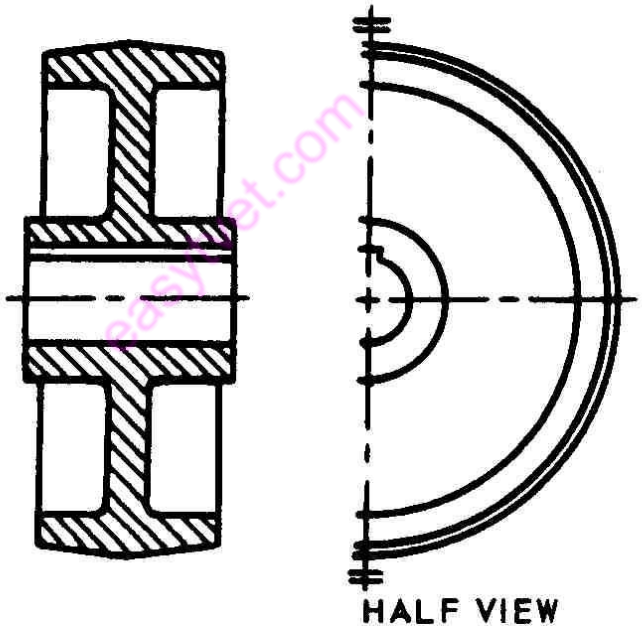
NB: Note that the extension lines can cross over *Object Lines* (Visible Edges of the Object) to reach their destination, but still leave a gap.

- ***Half Views and Partial Views-***

  used to simply save space when half of, or portion of a view is not needed or is redundant



Partial view



Half views

https://app.emaze.com/@AOLTOQWR#7

Figure 4;- partial views

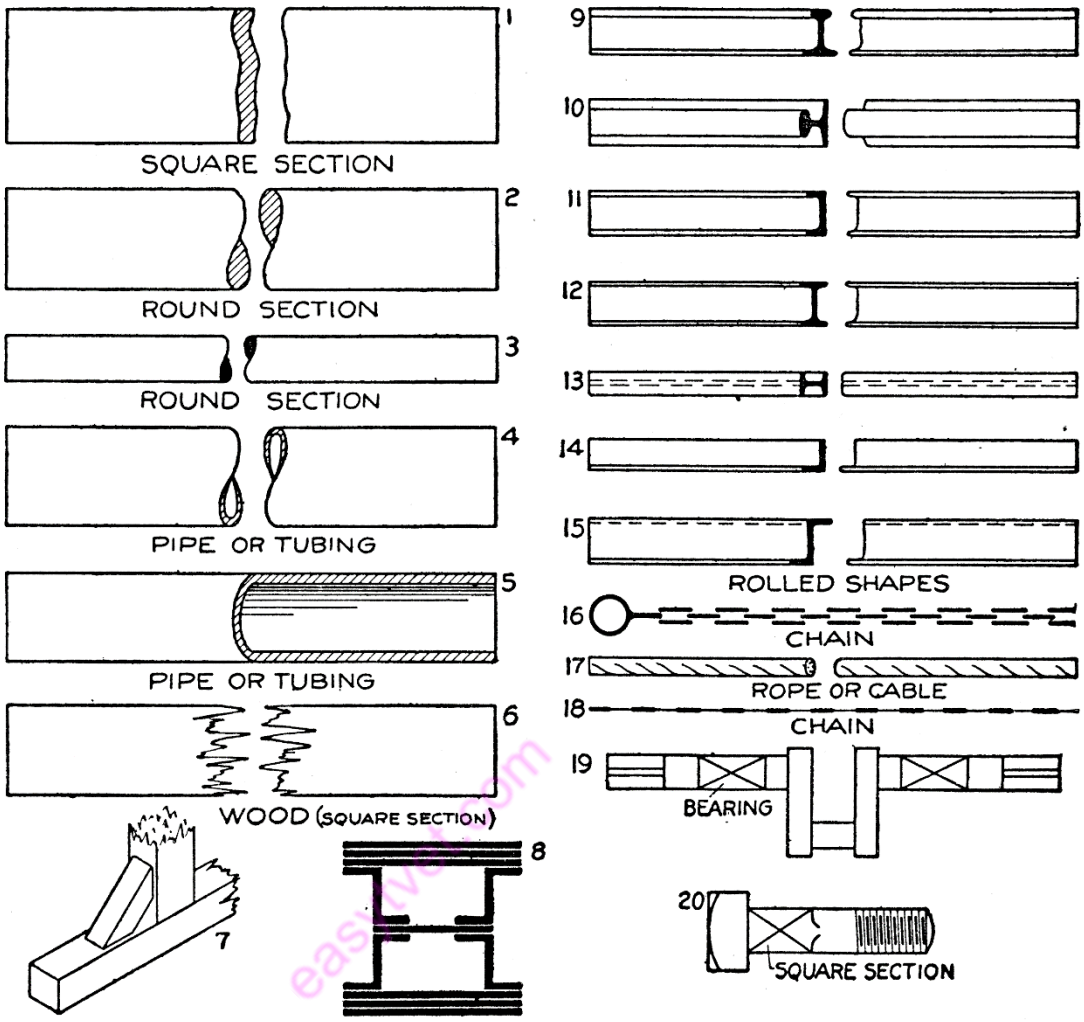
- ***Auxiliary Views***- used to accurately depict features on *Inclined Surfaces*.
- ***Sectional Views***
  - ***Full Section***-

Full section views cut all the way across the object. Views can be placed on the same page or on another page. The Cutting Plane and Arrows *always* are displayed.

- ***Half Section-***
  Half Section Views are used primarily on symmetrically shaped objects. They can depict the inside and outside of the object all in one view
- ***Offset (Sketched) Section-***
  are like full section views except that the Cutting Plane bends to follow certain features inside the object.
- ***Revolved Section-***
  shows the internal shape of an object without creating a completely separate section view. The cutting plane passes through the object at the desired location and is revolved, in place, to show the section view. Revolved Section Views are placed on the same page.
- ***Broken Out (Local) Section-***
  It is a way to make a section view of only a specific and usually small area. Broken Out Section Views are placed on the same page. The Cutting Plane and Arrows are not displayed.

➢ ***Detailed Views-***
Detailed views are created to show small, detailed areas of a view in a special scaled-up view. The scale is usually twice that of the normal view. Detailed Views can be placed on the same page or another page.

➢ ***Conventional Breaks-***
Conventional Breaks are a way of depicting a very long object without showing the entire length. It is often used for objects like rods, tubing/piping or wooden objects



https://etc.usf.edu/clipart/76600/76662/76662_breaketcsymb.htm

Figure 5;- conventional breaks and other symbols

- **Scaling-**

  Scaling is used to depict objects on paper that are either larger or smaller than the paper.

  NOTE:

  - If the object is larger than the paper, then the views of the object are scaled Down
  - If the object is smaller than the paper, then the views of the object are scaled Up
  - If the object fits on the paper, then the views are depicted at Full scale (1:1)

  In Drawings, Decimal Inch or Metric scaling are generally used. The number on the left of the colon indicates the units on the Page while the number on the

right of the colon indicates the Units on the Object. i.e. ***Paper : Object***. You want to think of it like this when you see a Decimal Inch scale of 1:2; O***ne unit on the paper = Two units on the object.***

b) A bill of quantities-

This is a document used in tendering in the construction industry in which materials, parts, and labour (and their costs) are itemized. It also (ideally) details the terms and conditions of the construction or repair contract and itemizes all work to enable a contractor to price the work for which he or she is bidding. The quantities may be measured in number, area, volume, weight or time. Preparing a bill of quantities requires that the design is complete and a specification has been prepared. The bill of quantities is issued to tenderers for them to prepare a price for carrying out the construction work. The bill of quantities assists tenderers in the calculation of construction costs for their tender, and, as it means all tendering contractors will be pricing the same quantities (rather than taking-off quantities from the drawings and specifications themselves), it also provides a fair and accurate system for tendering.

- **How to prepare bill of quantities**
  Bill of quantities are prepared by quantity surveyors and building-estimators, and "Indeed the bill of quantities was the raison d'être for the development of quantity surveying as a separate profession."

There are different styles of bills of quantities, mainly the elemental bill of quantities and trade bills.

(i) **Set up a spreadsheet for your bill of quantities.**

- Include columns for the item numbers, description, unit of measurement, quantity, rate for the item, labor, and total cost for the item. Your item numbers will be consecutive, starting from 1. Restart the item numbers for each section or category of the build.
- The columns for the rate for each item and total costs will be filled in by contractors bidding on the project. You typically won't have any values in those columns while you're drafting your BoQ.

(ii) **Prepare a list of materials you'll need to complete the project.**

- Look at the architect's plans and write a basic list of all the building materials required and the amounts needed of each. This includes wiring, hardware, and other fixtures.
- For example, if you're building a house, you might need framing materials, sheetrock, bricks, concrete, flooring materials, wiring, lighting fixtures, and kitchen and bathroom fixtures.

- Identify the unit of measurement for each of your materials. This may be a standard unit. For example, if you've included paint on your list of materials, the unit of measurement may be gallons or liters.
- Once you've determined the materials you'll need, fill them in on your spreadsheet. For example, if you need paint for your project, you might list "green paint" next to item #1. In the column for unit of measurement, you would write "gallons." Then you would include the number of gallons you needed in the quantity column. ***NB:*** You can add 15-20% to your material calculations to account for waste

(iii)**Break down the project into specific sections or categories.**

- Since different parts of your project will likely be handled by different contractors or subcontractors, split up your list of materials into those sections. That way, each contractor or subcontractor will know exactly what their costs will be for the project.
- If you're building a house, some different parts might include "framing," "plumbing," "electrical," "kitchen," "bath," and "flooring."
- Some materials may fall under more than one part. For example, if you have "framing" and "flooring," they may both need to use the same nails. This means you need to divide the overall number of nails you estimated between the two.

(iv) **Estimate the labor required to complete each part.**

- Based on the amount of work to be done, determine the number of man-hours it will take to finish. This should be a conservative estimate since some workers are more efficient than others.
- You can talk to contractors to get an idea of how many hours it would take to finish a given part. A quantity surveyor would usually be able to estimate this off the top of their head, based on their experience with similar projects.

(v) **Make an initial cost estimate based on the architect's design.**

- Look at the average prices for the materials and labor in your area. You can find out materials prices by checking hardware stores. To learn labor prices, you can talk to contractors in your area who work on similar projects.
- When you total your material prices and your labor costs, you'll have a general idea of how much money your project will cost to complete.
- Print off a separate copy of the BoQ for your initial cost estimate. This information isn't usually included on the official BoQ you submit to

contractors for bids. Use it to compare bids you get from contractors to find the best bid for your project.

(vi) Draft a schedule based on the estimates in the BoQ.

- Once you have labor estimates, it's possible to determine how long it will take to complete your project. Keep this schedule loose to account for things, such as weather, that could cause delays.
- For example, if you've estimated it will take 1,000 man-hours to build your house, assuming the contractors work 40 hours a week and there are no delays, it would take them 25 weeks to complete your house. However, to allow for delays, you're better off planning for it to take 30 to 40 weeks

➢ **Use of bill of quantity**

During construction stage, a bill of Quantity is used to provide a basis for the evaluation of the completed works for the purpose of making periodic payments (called interim payments) to the contractor who has been awarded the contract and proceeded with its execution.

c) A contingency sum-

A **contingency sum** is an amount of money, usually expressed as a percentage, included in the project budget to allow for the unknown or unresolved aspects of a design. There are two types of contingency sum.

(i) The first refers to a specific item, e.g., "additional alterations to services when installing said shower unit", where an item for alterations to existing services is not contained within the bill of quantities but some work is envisaged. usually approximated by the client's PQS

(ii) The second type of sum is where money can be allocated to any item, within the bill of quantities, in the same way as the above example or used as "additional work to be undertaken by the contractor, at the request of the contract administrator". Usually approximated by the contractors QS or commercial manager.

d) Quantity surveyor-

A professional in the construction industry who has expert knowledge on contracts and construction costs. Also known as chartered surveyors. they are responsible for managing all aspects of the contractual and financial side of a construction project ensuring that it is completed within the projected budget.

e) Valuation-

This is the process of determining the present value of an asset or a liability.

f) Tendering-

Making of a formal written offer to carry out work, supply goods, buy land or shares at a stated fixed price.

There are different types of a tenders namely:

- **Open tender-**
  Allows anyone to submit a tender to supply the goods or services required and offers an equal opportunity to any organization to submit the tender. Its the main tendering procedure employed by both government and private sectors.
- **Selective tender-**
  Only allows suppliers to submit tenders by invitation. The suppliers are known by their track records to be suitable for such a contract depending on size nature and complexity required.
- **Negotiated tender-**
  Extensively used in the engineering and construction industry commencing from tendering till dispute resolutions.it is highly appropriate for extending the scope of an existing contract reducing on costs and resulting in better communication and information flow.
- **Single-stage and two-stage tender-**

  (i) **Single stage tendering: -**

  Is used when all information required to calculate realistic prices is available at the start of the tender. An invitation is issued to prospective suppliers and a preferred tenderer is selected and may be appointed after negotiations.

  (ii) **Two-stage tender**- used to allow the early appointment of a supplier, prior to the completion of all the information required to enable them offer a fixed price. In the 1st stage, a limited appointment is agreed to allow work to begin while in the 2nd stage, a fixed price is negotiated for contract.

- **Serial tendering-** involves preparation of tenders based on a typical or notional bill of quantities or schedule of works
- **Framework tender-** allows client to invite from suppliers of goods and services to be carried out over a period on a call-off basis as and when needed.

g) Public procurement-

This method is used for public projects held by the government.

❖ Essential Construction Materials

Good quality construction materials are an essential component of any civil structure. Starting from TMT bars to cement, and bricks best quality building materials ensure that the concrete structure is both durable and profitable. And that is why utmost care should be taken while purchasing construction and raw materials. From bricks to TMT bars, every construction demands a few basic building materials. No construction work is complete if even one of the materials is missing.

- **Masonry: -**
  using individual units to build structures that are usually uses mortar to bound the units together. It is categorized into various categories based on several factors. Basic masonry are classified as :-
  (i) Stone masonry
  (ii) Brick Masonry and
  (iii) Block masonry

(i) Stone masonry

- Rubble masonry

https://gharpedia.com/blog/types-of-masonry/

Figure 1;- Rubble masonry

- Ashlar masonry

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Figure 2;- ashlar masonry

(ii) Brick masonry

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Figure 3; brick masonry

(iii) Block masonry
- Solid concrete block masonry
- Hollow concrete masonry
- AAC autoclaved concrete block masonry

(iv) Veneer masonry
(v) Gabion masonry
(vi) Composite masonry
(vii) Reinforced masonry

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Figure 4;-Hollow Concrete masonry

(viii) Bagged concrete masonry

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Figure 5;- bagged concrete masonry

- **Bonding material used**
  - Cement mortar used in brick Masonry

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Figure 6;- cement mortar in Brick masonry

- lime mortar used in Brick Masonry

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Figure 7;- lime mortar used Brick masonry

- Mud mortar used in Brick Masonry

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Figure 8;- masonry in mud mortar

- **Thickness of masonry**
  i. One brick masonry
  ii. Half brick masonry
  iii. One and half brick masonry

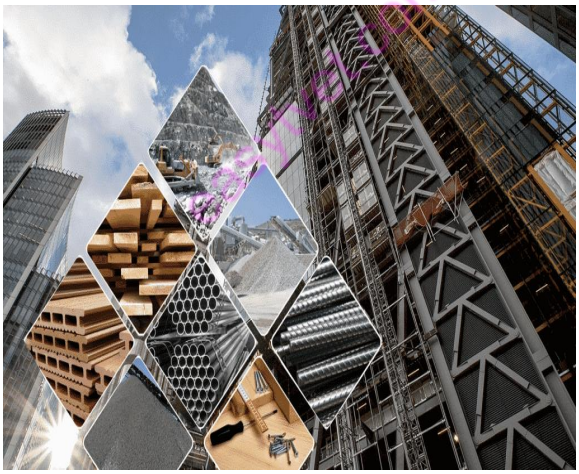

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Figure 9;- different building materials

➢ What Building Materials are Used in Construction?

There are many types of building materials used in construction such as :

- Concrete
- Steel
- Wood
- Brick
- Clay
- Cement
- Aggregate
- Stone
- Lime

Each material has different properties such as:

- Weight
- Strength
- Durability
- cost.

NB: The choice of materials for construction is based on cost and effectiveness to resisting the loads and stresses acting on the structure. As a structural engineer, one needs to work with their clients to decide on the type of materials used in each project depending on the size and use of the building.

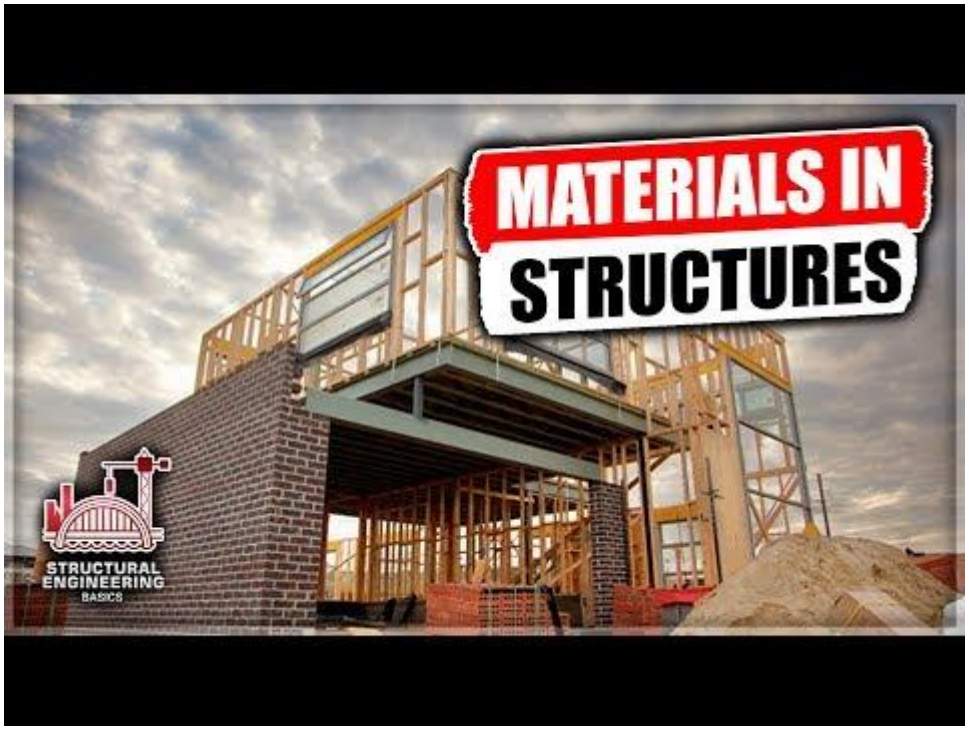

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Figure 10;- construction structures

The manufacturing of building materials is a well-established and standardized industry capable of providing a reliable supply of high-quality materials for their clients. The production of structural-grade building materials is subject to quality control procedures that involve inspection and testing according to national standards and scientific testing methods.

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Figure 11;-construction drawings

Part of the structural engineer's responsibilities is to prepare the project specifications including all building materials and applicable standards and provision to comply with.

This is a crucial part of any project to specify the quality and properties of materials to be used.
Building materials can generally be divided into two categories:

- Natural building materials such as stone and wood
- Man-made building materials such as concrete and steel.

NB: Both categories usually require a certain level of preparation or treatment before the use in a structural application.

Below is the list of materials used in most engineering consulting projects.

Material type		Sample compressive strength as Force (Newton) per unit area (mm^2)
Steel		300 MPa*
Concrete		25 MPa*
Masonry		10 MPa*
Wood	Parallel to grain	5 MPa*
	Perpendicular to grain	3.5 MPa*

*MPa: mega Pascal or N/mm2

i) Concrete :

Concrete is a composite material made from mixing cement, aggregates such as sand and crushed stone and water. The properties of concrete depend on the ratios used in the mix design.

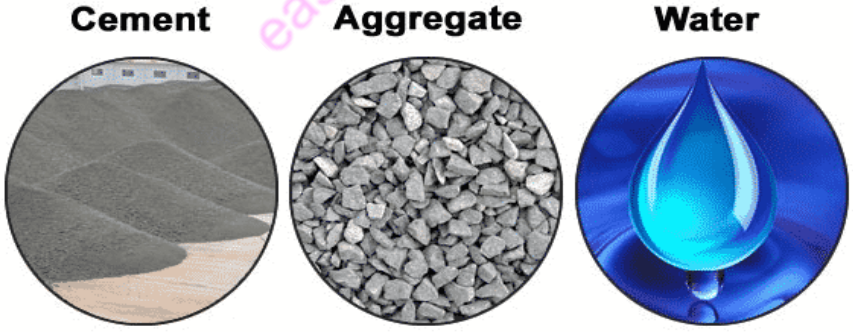

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Figure 15;- constituents of concrete

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Figure 16;- wet concrete

Classification of concrete

Classification of concrete is based on several factors such as;

- ***Cementing material:***
  - lime concrete
  - gypsum concrete
  - cement concrete.
- ***Perspective specification:***
  - M10- 1 (cement) : 3 (fine aggregate) : 6 (coarse aggregate)
  - M15- 1 (cement) : 2 (fine aggregate) : 4 (coarse aggregate)
  - M20- 1 (cement) : 1.5 (fine aggregate) : 3 (coarse aggregate)
  - M25- 1 (cement) : 1(fine aggregate) : 2 (coarse aggregate)
- ***Performance oriented specifications:***

- ***Grade of cement concrete:***
  - low strength concrete (< 20 N/mm2)
  - medium strength concrete (20–40 N/mm2)
  - high strength concrete (>40 N/mm2).
- ***Bulk density:***
  - super heavy (over 2500 kg/m3)
  - dense (1800-2500 kg/m3)
  - light weight (500–1800 kg/m3)
  - extra light weight concrete (below 500 kg/m3).

- ***Place of casting:***
  - ***in-situ concrete-*** When concrete is made and placed in position at the site
  - ***precast concrete-*** when used as a material for making prefabricated units in a factory.

NB; **Concrete** is very versatile and is a go to material for applications that require a combination of strength and durability. For example, concrete is an excellent material for building foundations where the weight of the structure meets the ground. This requires strength to carry the load and also durability to withstand the contact with the surrounding soil.

Concrete is very strong when exposed to compression stresses however, it's brittle and has limited tensile strength. When combined with steel rebar, reinforced concrete (fig 17) is stronger and more suitable for a wide range of structures such as;

- tall multi-story buildings
- bridges
- roads
- tunnels

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Figure 12;- reinforced concrete

ii) Steel:

Steel is the most suitable building material among metallic materials. This is due to a wide range and combination of physical and mechanical properties that steels can have. By suitably controlling the carbon content, alloying elements and heat treatment, a desired combination of hardness, ductility and strength can be obtained in steel.

- ***Manufacturing methods:***

The prominent steel-making processes are:

- Bessemer process
- Cementation process
- Crucible process
- Open Hearth process
- Electric Smelting process

- Duplex process
- Lintz and Donawitz (L.D.) process

➢ **Categories and uses of steel**

(i) Mild steel - Also known as low carbon or soft steel.

- It is ductile, malleable; tougher and more elastic than wrought iron.
- Mild steel can be forged and welded, difficult to temper and harden.
- It rusts quickly and can be permanently magnetized.

Uses:

- rolled sections
- reinforcing bars
- roof coverings
- sheet piles
- Railway tracks.

(ii) High carbon steel - It is also known as hard steel.

- The carbon content in high carbon steel varies from 0.55 to 1.50%.
- It is tougher and more elastic than mild steel.
- It can be forged and welded with difficulty.

❖ ***Uses:***

- Reinforcing cement concrete and pre-stressed concrete members.
- It can take shocks and vibrations and is used for making tools and machine parts.

(ii) High tensile steel- It is also known as high strength steel and is essentially a medium carbon steel.

- The carbon content in high tensile steel is 0.6–0.8%, manganese 0.6%, silicon 0.2%, Sulphur 0.05% and phosphorus 0.05%.
- Has a minimum elongation of 10 per cent.

❖ ***Uses:***

- concrete construction.

NB;

Steel is a relatively expensive building material so it is the structural engineer's responsibility to choose economic sizes and shapes according to the actual loads on the building to avoid overdesign.

The installation of steel is less time consuming compared to concrete and can be installed in any type of environment.

➢ ***Impurities on steel***

- ***Silicon-***

up to 1.75 per cent appears to increase both ultimate strength and elastic limit without decreasing ductility.

- ***Phosphorus-***
  The ductility of low-carbon steel decreases slightly by the presence of 0.3–0.5 per cent phosphorus. However, yield point, ultimate strength and hardness of steel are increased
- ***Manganese-***
  Manganese increases the tensile strength, hardenability and dilutes the effect of sulphur.
- ***Sulphur-***
  When Sulphur is present along with manganese it improves the machineability of steel.
- ***Copper-***
  increases resistance to corrosion when present in small percentage.
- ***Arsenic –***
  has a tendency to raise the strength and brittleness.
- ***Non-metalic impurities-***
  are mechanically suspended in the metal and are often called slag inclusions causing brittleness.

➢ ***Heat treatment on steel***

The purpose of heat treatment is to develop desired properties in steel as they can be controlled and changed as well by various heat treatments

- **Hardening:**

The objective of this treatment may be to secure a given hardness to a desired depth in steel.

- **Tempering:**

When a thick piece of steel is cooled rapidly it develops additional strains as the surface cools quicker than the interior. To relieve this strain, steel is subjected to the process tempering which consists in slowly heating the steel to a predetermined subcritical temperature and then cooling it slowly.

- **Annealing:**

The process consists of heating the steel to a temperature below the critical range, but high enough to obtain strain recrystallization and then cooled in any manner. Annealing of steel in addition to removing strain introduces one or more of the following properties:

  - Introduces softness, ductility and malleability.
  - Alters electrical, magnetic and other physical properties.
  - Produces a definite microstructure and grain refinement.
  - Removes gases.

- **Normalizing:**
  It consists in heating steel above critical range and cooling rapidly in air, but at rate slower than the critical cooling rate. The purpose of this heat treatment is to refine the grain structure resulting from rolling, forging or other manufacturing processes.

❖ **principle purposes of heat treatment**

- To enhance properties such as strength, ductility, hardness and toughness.
- To relieve internal stresses and strains.
- To refine the grain.
- To remove gases.
- To normalize steel after heat treatment.

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Figure 13;- wood structure

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Figure 14;- steel reinforcement bars

ii) Wood

Wood as a building material falls in two major classes:

- Natural
- Man-made.

With the advances in science and technology, wood in its natural form as timber, lumber, etc. is being rapidly replaced by composite wood materials in which natural wood is just a basic ingredient of a matrix or a laminate. The latter are found to be more useful and adaptable as they may be treated chemically, thermally or otherwise as per requirements. Some examples are;

- plywood
- fibreboards
- chipboards
- compressed wood
- impregnated wood, etc.

➢ ***Advantages:***

Wood has many advantages due to which it is preferred over many other building materials.

- It is easily available.
- easy to transport.
- easy to handle.
- has more thermal insulation.
- sound absorption.
- electrical resistance as compared to steel and concrete.
- It is the ideal material to be used in sea water.
- Wood is a good absorber of shocks and so is suitable for construction work in hilly areas which are more prone to earthquakes.
- wood can be easily worked on, repairs and alterations to wood work can also be done easily.

➢ ***Uses:***

Owing to the above-mentioned advantages, wood is very widely used in buildings as

- doors.
- Windows.
- Frames.
- temporary partition walls.
- roof trusses.
- ceilings apart from formwork.

➢ ***Characteristics of good timber***

The principal characteristics of timber of concern are strength, durability and finished appearance.

- Narrow annual rings, closer the rings greater is the strength.
- Compact medullary rays.
- Dark color.

- Uniform texture.
- Sweet smell and a shining fresh cut surface.
- When struck sonorous sound is produced.
- Free from the defects in timber.
- Heavy weight.
- No woolliness at fresh cut surface

➢ ***Classification of timber***

Wood is the hard, fibrous material that makes up the tree under the bark

Timber may be defined as a wood which retains its natural physical structure and chemical composition and is suitable for various engineering

Timber can be classified based on several features such as:

❖ **Position:**

- ***standing timber*-:**
  implies a living tree
- ***rough timber*-:**
  forms a part of a felled tree
- ***converted timber or lumber*-:**
  logs of timber sawn into planks or posts

❖ **grading:**

- ***structural grading*- :**
  graded based on the visible defects with known effects on the strength properties of the material
- ***stress grading* :-**
  grading based on consideration of maximum principle stresses to which it can be subjected
- ***commercial/yard/utility grading-:***
  principle by which materials are graded by considering the usefulness of the material and price factors
  - ***Grade A*-**
    Based on dimensions and general appearance where lengths, widths and thickness of converted materials are measured.
  - ***Grade B*-**
    Based on the best ultimate use of the material
  - ***Grade C*-**
    Based on qualitative evaluation of defects and rough estimate of turn out of utilizable material
  - ***Grade D*-** based on evaluation of units of defects and fixing permissible number of standard volume of area or the material in each grade

❖ **modulus of elasticity:**

- ***Group A*-**
  Modulus of elasticity in bending above 12.5kN/ mm^2
- ***Group B*-**
  Modulus of elasticity in bending above 9.8kN/$mm^2$and below 12.5kN/ mm^2

- ***Group C-***
  Modulus of elasticity in bending above 5.6 kN/$mm^2$and below 9.8kN/ mm^2

❖ **Availability-:**

This is based upon the figures supplied by the forest department:-

- *X*- Most common, 1415 m3 or more per year
- *Y*- Common, 355 m3 to 1415 m3 per year
- *Z*- Less common, below 355 m3 per year

❖ **Durability-:**

pieces of timber of 600*50*50 mm are half buried in the ground and their conditions noted at intervals from the observations, the average life span is calculated-:

- ***High durability-***
  average life of 120 months and over
- ***Moderate durability-***
  average life of less than 120 months but of 60 months or more
- ***Low durability-***

average life of less than 60 months

seasoning characteristics-:

this is based on the behavior of cracking and splitting during normal air seasoning

- ***Highly refractory (class A)*** –
  are slow and difficult to season-free from defects.
  Moderately refractory (class B) –
  may be seasoned free from surface defects of some protection is given against rapid drying.
- ***Non-refractory (class c)-***
  can be rapidly seasoned free from defects

❖ ***Treatability:***

This classification is based upon the resistance offered by the heartwood of a species to preservatives under a working pressure of 1.05 N/mm2 as:

- Easily treatable.
- Treatable but complete preservation not easily obtained.
- Only partially treatable.
- Refractory to treatment.
- Very refractory to treatment, penetration of preservative being practically impossible from the sides and ends.

➢ **Seasoning of timber**

This is the process of reducing moisture content of timber in order to prevent the timber from possible fermentation and making it suitable for use.

❖ ***Reasons for seasoning:***

- Reduce the shrinkage and warping after placement in structure
- Increase strength, durability and workability
- Reduce its tendency to split and decay
- Make it suitable for painting.
- Reduce its weight.

❖ ***Methods of seasoning;***

(i) Natural/air seasoning-

The log of wood is sawn into planks of convenient sizes and stacked under a covered shed in cross-wise direction in alternate layers (Fig. 4.2) so as to permit free circulation of air.

(ii) Artificial seasoning-

- ***Water seasoning-***
  The logs of wood are kept completely immersed in running stream of water, with their larger ends pointing upstream. Consequently the sap, sugar, and gum are leached out and are replaced by water. The logs are then kept out in air to dry
- ***Boiling-***
  exposing the wood to the action of steam spray is a very quick but expensive process of seasoning
- ***Kiln seasoning-***
  The scantlings are arranged for free circulation of heated air with some moisture or superheated steam. The circulating air takes up moisture required from wood and seasons it.
- ***Chemical/salt seasoning-***
  Common salt or urea are generally used; the latter is preferred as the corrosive action of common salt is a drawback.
- ***Electric seasoning-***
  Current is passed through the wood, being a bad conductor, wood resists the flow of current, generating heat in the process, which results in its drying. The drawback is that the wood may split.
- ***Mc. Neill's process-***
  has no adverse effects; it is the best method although most expensive. The timber is stacked in a chamber with free air space (l/3rd of its capacity) and containing products of combustion of fuels in the fire place. The time required for complete seasoning is 15 to 60 days.

iii) Clay

It is an earthen mineral rock capable of mixing with water and forming a plastic viscous mass which has a property of retaining shape when molded and dried.

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Figure 15;- clay soil

Purest clays consist mainly of kaolinite ($2SiO_2.Al_2O_3.2H_2O$) with small quantities of minerals such as quartz, mica, feldspar, calcite, magnetite, etc.

- ***Uses-:***
  - Clay bricks used for light-weight partition walls and floors as they possess high strength and resistance to fire.
  - Clay pipes on account of their durability, strength, lightness and cheapness are successfully used in sewers, drains and conduits.
- ***Classification of Clay:***

On the basis of resistance to high temperatures

- Refractory clay
- high melting clay
- low melting clay

iv) Bricks

A brick is rectangular in shape and of size that can be conveniently handled with one hand. Brick may be made of burnt clay or mixture of sand and lime or of Portland cement concrete.

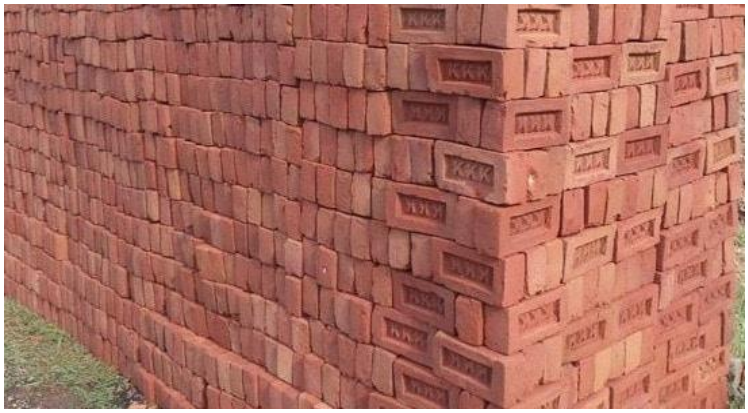

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Figure 16;- blocks of bricks

- ***Characteristics of a Brick***

  - Bricks are most popular and leading construction material because;
  - Cheap
  - Durable
  - Easy to handle and work with.

- ***Uses:***

  Clay bricks are used for;

  - building-up exterior and interior walls
  - partitions
  - piers
  - footings
  - Load bearing structures.

  Size of a standard brick (also known as modular brick) should be 19 × 9 × 9 cm and 19 × 9 × 4 cm. When placed in masonry the 19 × 9 × 9 cm brick with mortar becomes 20 × 10 × 10 cm.

  However, the bricks available in most part of the country still are 9" × 4.5" × 3" and are known as **field bricks.** Weight of such a brick is 3.0 kg. An indent called frog, 1–2 cm deep is provided for 9 cm high brick

- ***Classification of bricks***

  Bricks are classified based on the following factors:

  (i) Strength

Class	**Average comprehensive strength not less**

	than (N/mm^2)
35	**35**
30	**30**
25	**25**
20	**20**
17.5	**17.5**
15	**15**
12.5	**12.5**
10	**10**
7.5	**7.5**
5	**5**
3.5	**3.5**

Table 2; classification of bricks based on strength

(ii) Usage

- Common bricks
- Facing bricks
- Engineering bricks

(iii) Finish

- Sand-faced bricks
- Rustic bricks

(iv) manufacturing method

- Hand-made bricks
- Machine made

(v) Burning

- Pale bricks
- Body bricks
- Arch bricks

(vi) Types

- Solid bricks
- Perforated bricks
- Hollow bricks
- Cellular bricks

➢ Characteristics of good bricks

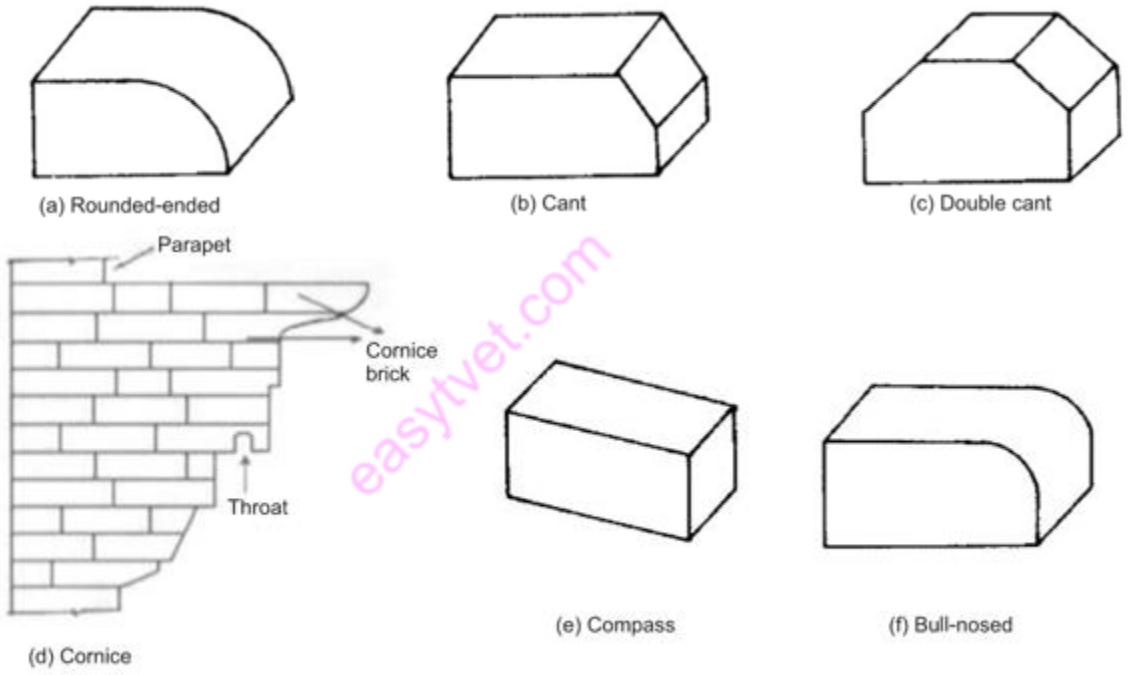
- ***Shape and size-***
  The bricks should have uniform size and plane, rectangular surfaces with parallel sides and sharp straight edges
- ***Color –***
  The brick should have a uniform deep red or cherry color
- ***Texture and compactness –***
  The surfaces should not be too smooth to cause slipping of mortar. A fractured surface should not show fissures, holes grits or lumps of lime.
- ***Hardness and soundness –***
  The brick should be so hard that when scratched by a finger nail no impression is made. When two bricks are struck together, a metallic sound should be produced.
- ***Water absorption-***
  should not exceed 20 per cent of its dry weight when kept immersed in water for 24 hours.
- ***Crushing strength-***
  should not be less than 10 N/mm2.
- ***Brick earth*** –
  should be free from stones, cankers, organic matter, saltpeter, etc.

➢ *Ingredients of good bricks and their functions*

- **Silica –**
  It enables the brick to retain its shape and imparts durability, prevents shrinkage and warping. Excess of silica makes the brick brittle and weak on burning
- **Alumina –**
  It absorbs water and renders the clay plastic. If alumina is present in excess of the specified quantity, it produces cracks in brick on drying
- **Lime -**
  Normally constitutes less than 10 per cent of clay. Lime in brick clay has the following effects:
  - Reduces the shrinkage on drying.
  - Causes silica in clay to melt on burning and thus helps to bind it.
  - In carbonated form, lime lowers the fusion point.
  - Excess of lime causes the brick to melt and the brick loses its shape.
  - Red bricks are obtained on burning at considerably high temperature (more than 800°C) and buff-burning bricks are made by increasing the lime content.
- **Magnesia –**
  Rarely exceeds 1%. It causes the clay to soften at slower rate than in most case is lime and reduces warping**.**

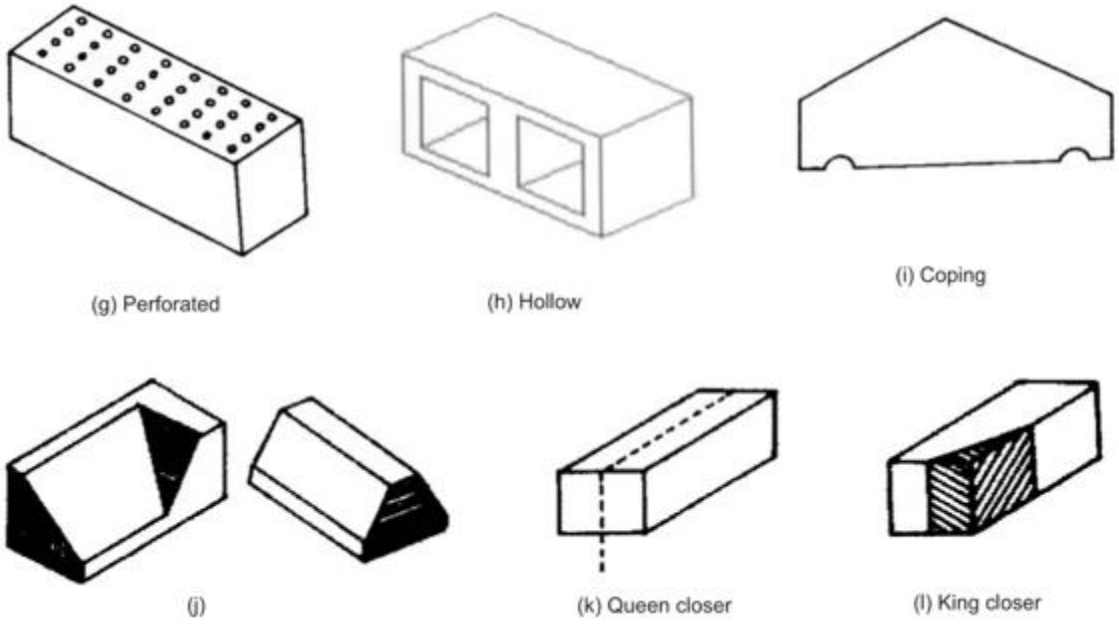
- **Iron –**
  Iron oxide constituting less than 7 per cent of clay, imparts the following properties:
  - Gives red color on burning when excess of oxygen is available and dark brown or even black color when oxygen available is insufficient; however, excess of ferric oxide makes the brick dark blue.
  - Improves impermeability and durability.
  - Tends to lower the fusion point of the clay, especially if present as ferrous oxide.
  - Gives strength and hardness

➢ ***Common type of bricks***



https://www.google.com/url?sa=i&url=http%3A%2F%2Fwww.constructionnews.co.in%2Fthe-types-of-bricks-used-in-building-construction.html&psig=AOvVaw3HM2k7OaRcGsRRIYZclQFW&ust=1626370425643000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOjc5ouM4_ECFQAAAAAdAAAAABAR

Figure 17 (a); common types of bricks



https://www.google.com/url?sa=i&url=http%3A%2F%2Fwww.constructionnews.co.in%2Fthe-types-of-bricks-used-in-building-construction.html&psig=AOvVaw3HM2k7OaRcGsRRIYZclQFW&ust=1626370425643000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOjc5ouM4_ECFQAAAAAdAAAAABAR

Figure 18 (b); common types of bricks

1.2.1.4 Learning Activities

a) Practical Activities

(i) Preparing a bill of quantities

Identify a project within the institution and prepare a realistic bill of quantities

(ii) Identifying different construction materials

Different materials used in construction are provided. Identify them and their features.

1.2.1.5 Self-assessment test

1. Which of the following is not an objective of seasoning timber?

   (i) Reduction in shrinkage and warping

   (ii) Reduction of weight

   (iii) Increase in strength and durability

   (iv) Reduction of natural defects in timber

2. Which of the following types of steels is used in the manufacture of rails?

   (i) Mild steel
   (ii) Manganese steel
   (iii) Cast steel
   (iv) Bessemer steel

3. Consider the following statements: A good soil for making bricks should contain (a) about 30% alumina, (b) about 10% lime nodule, (c) a small quantity of iron oxides and (d) about 15% magnesia.
   Which one of these statements are correct?
   (i) (a) and (b)
   (ii) (a) and (c)
   (iii) (a), (c) and (d)
   (iv) (b), (c) and (d)

4. Match List-I (Constituents of bricks) with List-II (Corresponding influence) and select the correct answer using the codes given below the lists: List-I List-II (Constituents of bricks) (Corresponding influence)

A. Alumina	1. Colour of brick
B. Silica	2. Plasticity recovery for moulding
C. Magnesia	3. Reacts with silica during burning and causes particles to unite together and development of strength
D. Limestone	4. Preserves the form of brick at high temperature and prevents shrinkage

Codes:

(a)	A	B	C	D
	2	1	4	3
(b)	A	B	C	D
	3	4	1	2
(c)	A	B	C	D
	2	4	1	3
(d)	A	B	C	D
	3	1	4	2

5. Which one of the following procedures is applied to determine the soundness of bricks?

(i) Immersing the bricks under water for 16 hrs and determining the quantity of water absorbed by the brick.
(ii) Immersing the brick under water for 24 hrs and determining its expansion using Le Chatelier apparatus.
(iii) Taking two bricks, hitting one against the other and observing whether they break or not and the type of sound produced while hitting.
(iv) Scratching the brick by finger nail and noting whether any impression is made or not.

1.2.1.6 Tools, equipment, Supplies and Materials

a) Tools and Equipment

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

b) Materials and Supplies

- Construction materials
- Computers
- Stationery

c) Personal protective equipment (PPEs)

- Safety boots
- Goggles
- Gas masks
- Helmets
- Gloves
- Dust coats
- First aid kit
- Ear muffs
- Dust masks
- Overalls

1.2.1.7 References

Allen, E., & Iano, J. (2019). Fundamentals of building construction: materials and methods. John Wiley & Sons.

Marani, A., & Nehdi, M. L. (2019). Integrating phase change materials in construction materials: Critical review. Construction and Building Materials, 217, 36-49.

Shubbar, A. A., Sadique, M., Kot, P., & Atherton, W. (2019). Future of clay-based construction materials–A review. Construction and Building Materials, 210, 172-187.

https://learnengineeringdrawing.blogspot.com/2016/05/orthographic-projection-in-first-angle.html

https://app.emaze.com/@AOLTOQWR#7

https://etc.usf.edu/clipart/76600/76662/76662_breaketcsymb.htm

https://gharpedia.com/blog/types-of-masonry/

https://www.google.com/imgres?imgurl=https%3A%2F%2Fwww.re-thinkingthefuture.com%2Fwp-content%2Fuploads%2F2020%2F06%2FA1075-Web-10-Different-construction-materials-around-the-globe.jpg&imgrefurl=https%3A%2F%2Fwww.re-thinkingthefuture.com%2Frtf-fresh-perspectives%2Fa1075-10-different-construction-materials-around-the-globe%2F&tbnid=o7DlEJpAb3uymM&vet=12ahUKEwi7ns-Zz9_xAhURWBoKHenyBk0QMygAegUIARC9AQ..i&docid=pLnP9DAH4_65tM&w=900&h=

585&q=different%20building%20materials&ved=2ahUKEwi7ns-Zz9_xAhURWBoKHenyBk0QMygAegUIARC9AQ

https://structuralengineeringbasics.com/what-types-of-construction-building-materials/

https://www.google.com/imgres?imgurl=https%3A%2F%2Fnexus.prod.postmedia.digital%2Fwp-content%2Fuploads%2F2019%2F11%2F1130-SO-DeGroot-scaled-2560.jpg&imgrefurl=https%3A%2F%2Fwww.theobserver.ca%2Fopinion%2Fcolumnists%2Fwhy-do-i-like-clay-soil&tbnid=bV44wecfkQIigM&vet=10CKcBEDMoqQFqFwoTCNiGy4qL4_ECFQAAAAAdAAAAABAC..i&docid=02NKprvQXth9zM&w=1920&h=2560&q=clay%20soil&ved=0CKcBEDMoqQFqFwoTCNiGy4qL4_ECFQAAAAAdAAAAABAC

https://www.google.com/url?sa=i&url=https%3A%2F%2Ftheconstructor.org%2Fbuilding%2Ftypes-of-bricks-identification-properties-uses%2F12730%2F&psig=AOvVaw0ynXICl9Q45mv43slaKQ_s&ust=1626370260269000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCICPmr2L4_ECFQAAAAAdAAAAABAK

https://www.google.com/url?sa=i&url=http%3A%2F%2Fwww.constructionnews.co.in%2Fthe-types-of-bricks-used-in-building-construction.html&psig=AOvVaw3HM2k7OaRcGsRRIYZclQFW&ust=1626370425643000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOjc5ouM4_ECFQAAAAAdAAAAABAR

1.2.1.8 Responses to self-assessment test 1

Q1. (iv)

Q2. (ii)

Q3. (i)

Q4. (iii)

Q5. (iii)

1.2.6 1.2.2 LEARNING OUTCOME 2: IDENTIFY PROPERTIES OF CONSTRUCTION MATERIALS

1.2.2.1 Introduction to learning outcome

This learning outcome specifies the content of competencies required to Identify properties of construction materials. It includes; Physical properties of construction

materials ,Chemical properties of construction materials and Mechanical properties of construction materials.

1.2.2.2 performance Standard

a) ***Physical properties*** of construction materials are identified based on the type of construction material and codes of practice
b) ***Chemical properties*** of construction materials are identified based on the type of construction material and codes of practice.
c) ***Mechanical properties*** of construction materials are identified based on the type of construction material and codes of practice

1.2.2.3 Information sheet

a) Terms and concepts

Building materials have an important role to play in this modern age of technology. Although their most important use is in construction activities, no field of engineering is conceivable without their use. Due to the great diversity in the usage of buildings, installations and the various processes of production, a great variety of requirements are placed upon building materials calling for a very wide range of their properties:

- strength at low and high temperatures.
- Resistance to ordinary water and sea water, acids and alkalis etc.
- Materials for interior decoration of residential and public buildings, gardens and parks, etc. should be, by their very purpose, pleasant to the eye, durable and strong.

NB; The principal properties of building materials predetermine their applications. Only a comprehensive knowledge of the properties of materials allows a rational choice of materials for specific service conditions

b) Physical properties

These properties characterize its structure or relation to the physical processes of the environment. These include -:

- **Mass**- is the amount of matter or substance that makes up an object.

- **true and average density**

  - True density - the ratio of mass to volume of the material in an absolutely dense state, i.e., without pores and voids. To determine the true density r (kg / m 3, g / cm 3), it is necessary to divide the mass of the material (sample) m (kg, g) by the absolute volume V (m 3, cm 3) occupied by the material itself (without pores):

- Average density - This is a physical quantity determined by the ratio of the mass of the material sample to the entire volume occupied by it, including the pores and voids present in it. The average density r (kg / m 3, g / cm 3) is calculated by the formula: where m is the mass of the material in its natural state; V is the volume of material in its natural state.

NB: most materials have pores, so their average density is always lower than the true density. Only in dense materials (steel, glass, bitumen, and some others) are the true and average densities equal, because their internal pore volume is very small

❖ **Porosity of a material** - this is the degree of filling it with pores. Porosity complements the density up to 1 or up to 100%. The porosity of various materials:

- Glass, metal 0%;
- Heavy concrete 5 - 10%;
- Brick 25 - 35%;
- Aerated concrete 55 - 85%;
- Polyfoam 95%,

NB; Density and porosity directly affect such characteristics of materials as water absorption, water permeability, frost resistance, strength, thermal conductivity, etc.

❖ **water absorption -** the ability of the material to absorb water and retain it. The amount of water absorption is determined by the difference in the mass of the sample in water saturated and absolutely dry.

- ➢ Volumetric water absorption is distinguished when the difference is related to the volume of the sample.
- ➢ Mass water absorption is when the difference is attributed to the mass of the dry sample. Mass water absorption for some materials:
  - Granite 0.5 - 0.8%.
  - Heavy concrete 2 - 3%.
  - Ceramic brick 8 - 20% **.**
- Porous heat-insulating materials, for example, peat cookers\u003e 100%.

NB; The saturation of materials with water adversely affects their basic properties: it increases density and thermal conductivity, reduces strength.

❖ **water loss**

❖ **Humidity-** moisture content, referred to the mass of the material in a dry state. The moisture content of the material depends both on its ability to absorb moisture in the material itself and on the environment in which the material is located**.**

- **Hygroscopicity-** the property of materials to absorb a certain amount of water with increasing ambient humidity. This property is typical, for example, for wood - to avoid this, apply protective coatings**.**

- **Water permeability-** the property of a material to pass water under pressure. It is characterized by the amount of water passed in 1 hour through 1 cm 2 the area of \u200b\u200bthe test material at constant pressure. Especially dense materials (steel, glass, bitumen) and dense materials with closed pores (for example, concrete of a specially selected composition) are waterproof.

- **Air, gas and vapor permeability-** the property of a material to pass water vapor or gases, including air, through its thickness under pressure. All porous materials in the presence of open pores are able to pass steam or gas.

NB; Steam and gas permeability is characterized by a coefficient that is determined by the amount of steam or gas in liters passing through a layer of material 1 m thick and 1 m 2 in area for one hour with a partial pressure difference of 133.3 Pa on the opposite walls.

- **Heat /Thermal conductivity –**

the property of the material to transfer heat through the thickness in the presence of a temperature difference on the surfaces that bound the material. the ;thermal conductivity of the material is estimated by the amount of heat passing through the wall of the test material 1 m thick, 1 m 2 in 1 hour at a temperature difference of the opposite surfaces of the wall 1 0 C. The thermal conductivity is measured in W / (m · K).

NB;

The thermal conductivity of a homogeneous material depends on its average density in that a decrease in the density of the material, thermal conductivity decreases and vice versa. The moisture conductivity significantly affects the material's thermal conductivity wet materials are more heat-conducting than dry materials, since the thermal conductivity of water is 25 times greater than the thermal conductivity of air. With increasing temperature, thermal conductivity increases.

The thermal conductivity of a material depends on many factors:

- the nature of the material.
- Structure.
- Porosity.
- Humidity.
- the average temperature at which heat transfer occurs.

The material of the crystalline structure is usually more thermally conductive than the material of the amorphous structure. If the material has a layered or fibrous structure, then its thermal conductivity depends on the direction of the heat flux with respect to the fibers, for example, the thermal conductivity of wood along the fibers is two times greater than across the fibers.

❖ **heat capacity- -**

the property of a material to absorb a certain amount of heat when heated and to release it when cooled. The heat capacity indicator is the specific heat capacity equal to the amount of heat (J) required to heat 1 kg of material per 1 0 C.

- Specific heat, KJ / (kg · 0 C):
- Artificial stone materials 0.75 - 0.92;
- Wood 2.4 - 2.7;
- Steel 0.48
- Water 4.187.

NB; The heat capacity is taken into account when calculating the heat resistance of walls and ceilings of heated buildings, as well as when calculating furnaces.

❖ **fire resistance -** the ability of the material to withstand the effects of high temperatures and water in a fire. According to the degree of fire resistance, the materials are divided into:

- ***non-combustible***- Fireproof materials under the influence of fire or high temperature do not ignite, do not smolder and do not char eg.
  - Steel.
  - Concrete.
  - Brick.
- ***difficult to combust*** Hardly combustible materials under the influence of fire are difficult to ignite, smolder, or char, but after removing the source of fire, their burning and decay cease e.g.
  - wood-cement material fiberboard.
  - asphalt concrete.
  - some types of polymeric materials.
- ***combustible-*** under the influence of fire or high temperature ignite and continue to burn after removing the source of fire eg.
  - Wood.
  - Felt.
  - roofing material.

❖ **refractoriness-**

the property of the material to withstand prolonged exposure to high temperature, without melting and without deformation. According to the degree of refractoriness, the materials are divided into refractory (they withstand temperatures over 1580 0 C for a long time), refractory (1350 - 1580 0 C) and low-melting, softening at temperatures below 1350 0 C (ordinary clay brick is also referred to them).

❖ **Moisture return-**

the property of the material to give moisture to the surrounding atmosphere. It is determined by the amount of water (in percent by weight or volume of a standard sample) lost by the material per day at an ambient humidity of 60% and a

temperature of 20 0 C. The water evaporates until an equilibrium is established between the moisture of the material and the humidity of the surrounding air.

- **Frost resistance –**
  the property of water-saturated material to withstand multiple alternate freezing and thawing without signs of destruction and a significant decrease in strength.

NB;

Water freezing increases in volume by 9%, and if it completely fills the pores, the ice will destroy the pore walls, but usually the pores are not completely filled, therefore, destruction can occur with repeated freezing and thawing.

- Dense materials that do not have pores, or materials with insignificant open porosity, the water absorption of which does not exceed 0.5%, have high frost resistance. Frost resistance is of great importance for wall, foundation and roofing materials that are systematically subjected to alternate freezing and thawing.

https://www.google.com/imgres?imgurl=https%3A%2F%2Fi0.wp.com%2Ftheconstructor.org%2Fwp-content%2Fuploads%2F2016%2F12%2Ffrost-resistance-of-building-materials.jpg%3Fresize%3D565%252C200%26ssl%3D1&imgrefurl=https%3A%2F%2Ftheconstructor.org%2Fbuilding%2Fproperties-of-building-materials-construction%2F14891%2F&tbnid=-n7Dtp-WtNUTiM&vet=10CEUQMyjkAWoXChMIkPHOxpTj8QIVAAAAAB0AAAAAEAM..i&docid=-VxuRbMw_aTYjM&w=565&h=200&q=illustration%20of%20frost%20resistance&ved=0CEUQMyjkAWoXChMIkPHOxpTj8QIVAAAAAB0AAAAAEAM

Figure 19;- illustration of frost resistance

c) Mechanical properties

- **The important mechanical properties considered for building materials are:**

- ***Strength-***
  Its ability to withstand an applied load without failure or plastic deformation.
  Compressive strength-
  Maximum stress a material can withstand before compressive failure (MPa)
- ***Tensile-***
  The test specimens of metals for tensile strength are round bars or strips and that of binding materials are of the shape of figure eight.
- ***Bending-***
  Bending Strength tests are performed on small bars (beams) supported at their ends and subjected to one or two concentrated loads which are gradually increased until failure takes place.
- ***Impact-***
  Is the ability of a material to resist penetration by a harder body.

NB; **The** importance of studying the various strengths will be highlighted from the fact that materials such as stones and concrete have high compressive strength but a low (1/ 5 to 1/ 50) tensile, bending and impact strengths.

- ***Hardness-***
  Ability to withstand surface indentation and scratching
- ***Plasticity-***
  Ability of a material to undergo irreversible or permanent deformations without breaking or rupturing
- ***Ductility-***
  Materials can be drawn out without necking down, the examples being copper and wrought iron.
- ***Brittleness-***
  Materials have little or no plasticity. They fail suddenly without warning. Cast iron, stone, brick and concrete are comparatively brittle materials .
- ***Elasticity-***
  is the ability of a material to change its shape under load without cracking and to retain this shape after the load is removed. Some of the examples of plastic materials are steel, copper and hot bitumen.

NB; Within the limits of elasticity of solid bodies, the deformation is proportional to the stress. Ratio of unit stress to unit deformation is termed as modulus of elasticity. A large value of it represents a material with very small deformation**.**

- ***Abrasion resistance-***
  refers to the ability of materials and structures to withstand abrasion. It is a method of wearing down or rubbing away by means of friction. This ability helps to keep the material's original structure and look.
- ***Malleability-***
  Ability of the material to be flattened into thin sheets under applications of heavy compressive forces without cracking by hot or cold working means.

NB; The common characteristics of building materials under stress are ductility, brittleness, stiffness, flexibility, toughness, malleability and hardness.

d) Chemical Properties of Building Materials

The properties of materials against the chemical actions or chemical combinations are termed as chemical properties. And they are-:

- ***Chemical Resistance –***
  The ability of a construction materials to resist the effects by chemicals like acids, salts and alkalis is known as chemical resistance. Underground installations, constructions near sea etc. should be built with great chemical resistance.
- ***Corrosion Resistance-***
  Formation of rust (iron oxide) in metals, when they are subjected to atmosphere is called as corrosion. So, the metals should be corrosive resistant. To increase the corrosion resistance proper measures should be considered. Otherwise it will damage the whole structure.

https://www.google.com/url?sa=i&url=http%3A%2F%2Fages1.com%2Fvci.htm&psig=AOvVaw1gNgF_24aecTuhopgFmKMj&ust=1626372875447000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLD-25eV4_ECFQAAAAAdAAAAABAD

Figure 20;- corrosion resistance

1.2.2.4 Learning Activities

a) Practical Activities

- To determine the densities of different types of building materials.
- Samples of clay tiles, common stones, timber are provided when oven dried each is to be weighed and their weight recorded on a table.

- Their volume is determined and recorded
- To get their density (p)=mass /volume

1.2.2.5 Self-assessment

Q1. Which are the four classification of building materials properties

Q2. (a) Why is it important to study the properties of building materials?

(b) List and define the physical properties of building materials.

Q3. What is the difference between metals and non-metals

Q4. Which are the four electrical properties of a material

1.2.2.6 Tools, Equipment, Supplies and Materials

a) Tools and equipment

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

b) Materials and supplies

- Computer software
- Construction materials
- Computers
- Stationery
- Manufacturer's catalogues

c) Personal protective equipment (PPEs)

- Safety boots
- Goggles
- Gas masks
- Helmets
- Gloves
- Dust coats
- First aid kit
- Ear muffs

- Dust masks
- Overalls

1.2.2.7 References

Doran, D., & Cather, B. (Eds.). (2013). *Construction materials reference book*. Routledge.

Duggal, S. K. (2017). *Building materials*. Routledge.

Hornbostel, C. (1991). *Construction materials: Types, uses and applications*. John Wiley & Sons.

Lima, C., Caggiano, A., Faella, C., Martinelli, E., Pepe, M., & Realfonzo, R. (2013). Physical properties and mechanical behaviour of concrete made with recycled aggregates and fly ash. *Construction and Building Materials*, *47*, 547-559.

SanthiRaj, P., & Sireesha, P. (2017). STUDY ON PROPERTIES OF CONSTRUCTION MATERIALS. *Gokaraju Rangaraju Institute of Engineering & Technology*, 202.

https://www.google.com/imgres?imgurl=https%3A%2F%2Fi0.wp.com%2Ftheconstructor.org%2Fwp-content%2Fuploads%2F2016%2F12%2Ffrost-resistance-of-building-materials.jpg%3Fresize%3D565%252C200%26ssl%3D1&imgrefurl=https%3A%2F%2Ftheconstructor.org%2Fbuilding%2Fproperties-of-building-materials-construction%2F14891%2F&tbnid=-n7Dtp-WtNUTiM&vet=10CEUQMyjkAWoXChMIkPHOxpTj8QIVAAAAAB0AAAAAEAM..i&docid=-VxuRbMw_aTYjM&w=565&h=200&q=illustration%20of%20frost%20resistance&ved=0CEUQMyjkAWoXChMIkPHOxpTj8QIVAAAAAB0AAAAAEAM

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1.2.2.8 Responses to self-assessment

Q1. The four classification of building materials properties are-:

- Physical properties
- Chemical properties
- Mechanical properties
- Electrical properties

Q2. (a) Importance of studying properties of Building

- To ensure that the materials used do not deteriorate in time

- To understand the chemical composition of the materials to avoid using reacting materials
- To be able to select materials of high strength which can with stand imposed loads
- To reduce the rate of expansion in building materials due to changes in temperature
- To control the heat subjected by some material with high thermal conductivity

Q2. (b) Physical properties of building materials are:

- ***Melting or freezing point;***
  It is the temperature at which the solid and liquid phase can exist in stable equilibrium
- ***Density;***
  It's the Mass per unit volume
- ***Thermal Conductivity;***
  This is the number of kilojoules of heat that would flow per second through a specimen
- ***Boiling point;***
  the of a liquid is the temperature at which its vapor pressure equal to one atmosphere
- ***electrical resistivity;***
  It's the reciprocal of its conductivity of a material

Q3. The difference between metals and non-metals are:

S no	Property	Metal	Non metal
1	Structure	All solid metals have crystalline structure	They exist in mophic or mesomorphic form
	State	Generally solid at room temperature	Gases and solid at ordinally room temperature
	Lustre	Poses metallic lustre	Do not poses metallic lustre except iodine and graphite
	Conductivity	Good conductors od heat and electricity	bad conductors od heat and electricity
	Ductility	Ductile	Not ductile

Q4. The four electrical properties of a material are:

- Resistivity Conductivity

- Conductivity
- Temperature Coefficient of Resistance
- Dielectric Strength

1.2.3 LEARNING OUTCOME 3: MANUFACTURE OF CONSTRUCTION MATERIALS

1.2.3.1 Introduction to learning outcome

This learning outcome specifies the content of competencies required to Manufacture construction materials. It includes; Raw materials used in manufacturing construction materials, Procedures of manufacturing construction materials and Plant and equipment used in manufacturing construction materials.

1.2.3.2 Performance standards

a) Raw materials are identified based on construction materials to be produced
b) Construction materials are manufactured as per manufacturing procedures

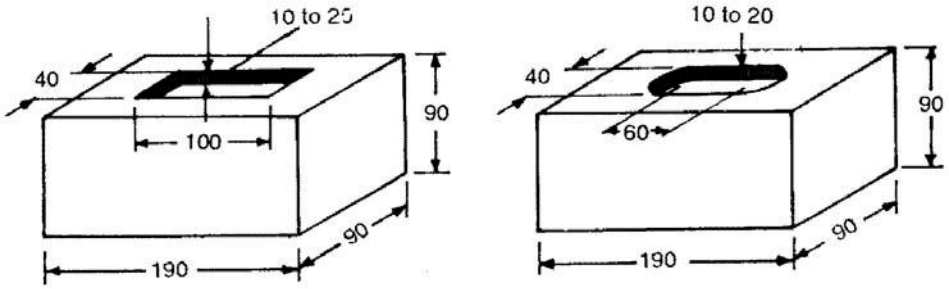
1.2.3.3 Information sheet

a) Definition of terms and concepts

- **Vitrification** –
  This is the transformation of a substance into glass or a crystalline non-amorphous solid.
- **Dehydration**-
  This is the complete draining of water which had been retained in the pores of a material.
- **Oxidation**-
  This is the reaction of a metal or a non-metal with oxygen to form an oxide
- **Tempering**-
  This is the process of improving the hardness and elasticity of steel or other metal by reheating an then cooling it.

b) BRICKS

Size of a standard brick - (also known as modular brick) should be 19 × 9 × 9 cm and 19 × 9 × 4 cm. When placed in masonry the 19 × 9 × 9 cm brick with mortar becomes 20 × 10 × 10 **cm**



https://civilblog.org/2015/04/08/what-are-the-quality-requirements-of-common-clay-building-bricks/

Figure 21;- bricks

❖ **Procedures of manufacturing bricks** :

➢ **Raw materials in manufacture of bricks**

- ***Clay-***
  It is an earthen mineral mass or fragmentary rock capable of mixing with water and forming a plastic viscous mass which has a property of retaining its shape when molded and dried.
- ***Purest clays-***
  consist mainly of kaolinite ($2SiO_2.Al_2O_3.2H_2O$) with small quantities of minerals such as quartz, mica, felspar, calcite, magnetite, etc.
- ***fly ash-***
  A waste material available in large quantities from thermal power plants can be added to alluvial, red, black, marine clays, etc.
- ***sandy loam –***
  Addition of sandy loam is often found effective in controlling the drying behavior of highly plastic soil mass containing expanding group of clay minerals.
- ***Rise husk rice –***
  The ash should preferably have unburnt carbon content in the range of 3–5% and should be free from extraneous materials.
- ***Basalt stone dust –***
  Basalt stone occurs underneath the black cotton soil and its dust is a waste product available in large quantity from basalt stone crushing units

➢ **Selection of suitable type of brick earth:**

Good quality building bricks cannot be made from every type of earth or soil. As a general statement, it may be said that any soil (earth) which contains four parts of clay and one part of sand is suitable for making bricks.

This is, however, a general statement. A suitable earth should have various constituents in the following proportions:

- **Alumina (20-30%).**
  All clays are basically hydrous aluminum silicates. Clays are responsible for the plastic character of the mud.

If they are present in higher proportions, the brick will shrink on drying (and develop cracks). If they are present in smaller proportions, the brick will not be molded easily and nicely.
The above percentage of alumina (20-30%) imparts the bricks sufficient plasticity.

- **Silica (50-60%).**
  This is present in two forms: the silica combined as a constituent of clay, and, the free silica (sand or quartz).
  The total proportion of silica should form about 50-60 percent. (It is why the actual clay content and free sand content has to be broadly in the ratio of 4 : 1 in the good brick earth).
  Silica is responsible for strength, hardness, and resistance to shrinkage and shape of the brick, and, also to a great extent, for its durability or long life.
  But if we add too much free sand in the brick earth and thereby raise the proportion of total silica in the earth, resulting bricks would be very brittle and porous and may not burn easily.

- **Lime (4%).**
  This component makes burning and hardening of bricks quicker and therefore is considered desirable with following two conditions:

(a) it would not be more than 4% because in that case, it may cause excessive softening of bricks on heating (Lime and Magnesia act as fluxes).

(b) it must be present only in a finely powdered and thoroughly dispersed form. Otherwise, if present in small grains or nodules, the lime itself will get slaked (heated) and once the brick is used, it (lime) will easily get hydrated and cause disintegration of brick.

Magnesia, which is invariably associated with lime, also has a similar effect. It is their total percentage which must be considered while determining the composition of the brick earth.

- **Iron Oxide (4-6%)**.
  Like oxides of calcium and magnesium, iron oxide also acts as a flux, i.e. it lowers down the softening temperature of silica.
  The iron oxide has, in addition, another important function: it imparts the red color to the bricks.
  The excess of this oxide will make the bricks too soft during burning (where there is a risk of deformation) besides making them darker in appearance.
  A shortage of iron oxides in the earth will affect the final color of the bricks: instead of being brick red, they may be yellow or light red.
  (The yellow color may also be due to incomplete burning of bricks).

Besides the above desired essential constituents of good brick earth, there are some materials which should not be present in the good quality brick earth at all, even in a small percentage.

They are listed below with their harmful effects.

(i) Lime Nodules.

Free lime nodules will hinder in proper burning. They will also adversely affect the quality of final brick.

(ii) Organic Matter.

This includes roots of grasses, leaves and other vegetable matter. Such matter will affect the quality of brick if left incompletely burnt during the process.

(iii) Sulphides and Sulphates.

Iron sulphide in the form of Pyrite and alkalies in the form of potash and soda are some other common impurities present in many soils.

The effect of iron sulphide is that it creates disintegration or cracking in the brick during the burning stage.

In the case of alkalies, besides their pronounced flux-action similar to lime and magnesia, they are liable to stay back in the final brick.

When such a brick is used in a building, the alkalies absorb moisture from the atmosphere very easily.

They get dissolved into it and when this water is evaporated from the surface, they reappear in the form of a scum or encrustation or patches of white salt. This phenomenon is called, *efflorescence* is a common cause of dis-figuration of such a brickwork made from alkaline soils.

Summarizing, the ideal composition of a good brick earth is:

- Clay 20-30%.
- Silica (Total, free and combined 50-60%).
- CaO, MgO 4-5%.
- Iron Oxide -4-6 %.
- The earth should be free from alkalies, organic matter, free lime and organic matters as far as possible.

➢ Preparation of clay for brick manufacturing

Preparation of clay for bricks manufacturing is done in six steps:

Namely: (i) unsoiling, (ii) digging, (iii) cleaning ,(iv) Weathering, (v) Blending and (vi) Tempering.

i. Un-soiling –

About 20 cm of the top layer of the earth, normally containing impurities like; stones, pebbles, gravel, roots, etc., is removed after clearing the trees and vegetation.

ii. Digging –

The soil mass is then manually excavated, puddled, additives such as fly ash, sandy loam, rice husk ash, and stone dust spread over the plane ground surface on volume basis, watered and left over for weathering and subsequent processing. The digging operation should be done before rains.

iii. Cleaning-

In this stage, the clay is cleaned of stones, vegetable matter etc. if large quantity of particulate matter is present, then the clay is washed and screened. The lumps of clay are converted into powder with earth crushing rollers.

https://theconstructor.org/building/manufacturing-of-bricks-methods-and-process/11972/

fig. 26 – cleaning of impurities

iv. Weathering –

The cleaned clay is exposed to atmosphere for softening. Stones, gravels, pebbles, roots, etc. are removed from the dug earth and the soil is heaped on level ground in layers of 60–120 cm. The soil is left in heaps and exposed to weather for at least one month This is done to :

- To develop homogeneity in the mass of soil
- To eliminate the impurities which get oxidized.

Soluble salts in the clay would also be eroded by rain to some extent.

NB;

- The soil should be turned over at least twice
- it should be ensured that the entire soil is wet throughout the period of weathering.

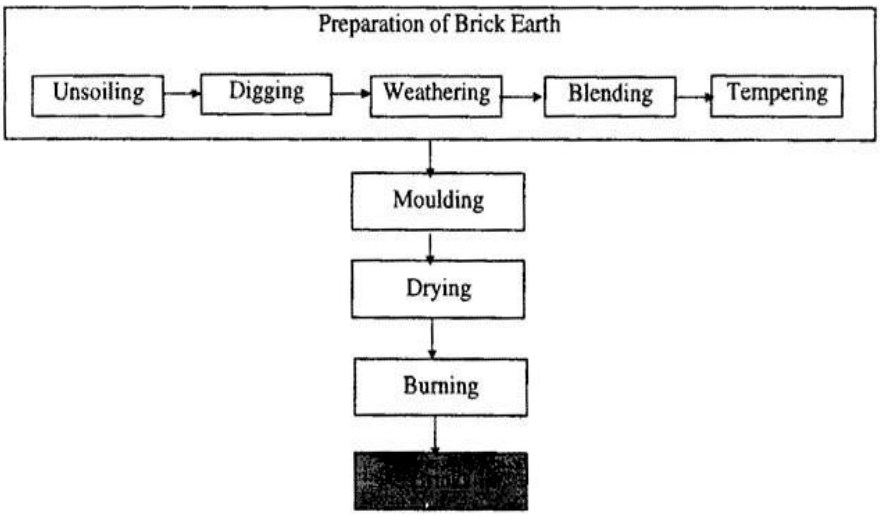


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Figure 27;-preparation of brick earth

v. Blending –

If we want to add any ingredient to the clay, it is to be added in this stage by making the clay loose and spread the ingredient over it. The earth is then mixed with sandy-earth and calcareous-earth in suitable proportions to modify the composition of soil. Moderate amount of water is mixed so as to obtain the right consistency for molding. The mass is then mixed uniformly with spades.

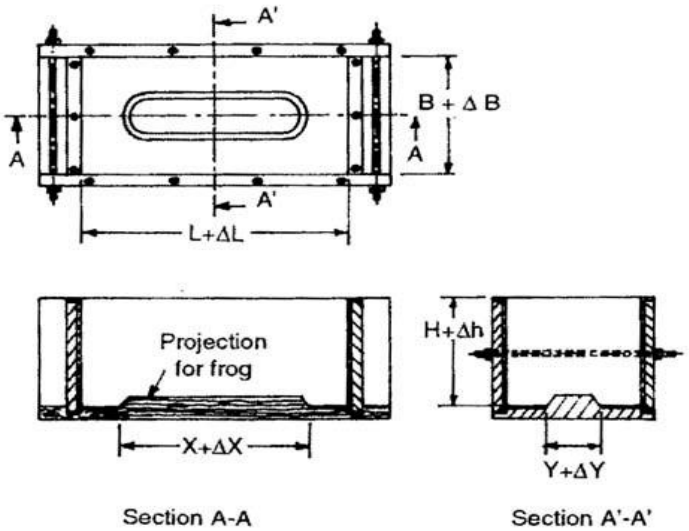

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Figure 28;- blending process

vi. Tempering-

In this stage, water is added to clay and pressed or mixed. The pressing will be done by cattle or with feet of men for small scale projects, pug mill is used as grinder for large scale projects. So, the clay obtains the plastic nature and now it is suitable for molding. It involves kneading the earth with feet to make the mass stiff and plastic.

https://i1.wp.com/theconstructor.org/wp-content/uploads/2016/06/tempering-of-clay-for-manufacturing-of-bricks.jpg?resize=476%2C370&ssl=1

Fig. 29- Tempering for Small scale projects

A pug mill-

A pug mill consists of a conical iron tub with cover at its top. It is fixed on a timber base which is made by fixing two wooden planks at right angles to each other. The bottom of tub is covered except for the hole to take out pugged earth. The diameter of pug mill at bottom is about 800 mm and that at top is about one metre.

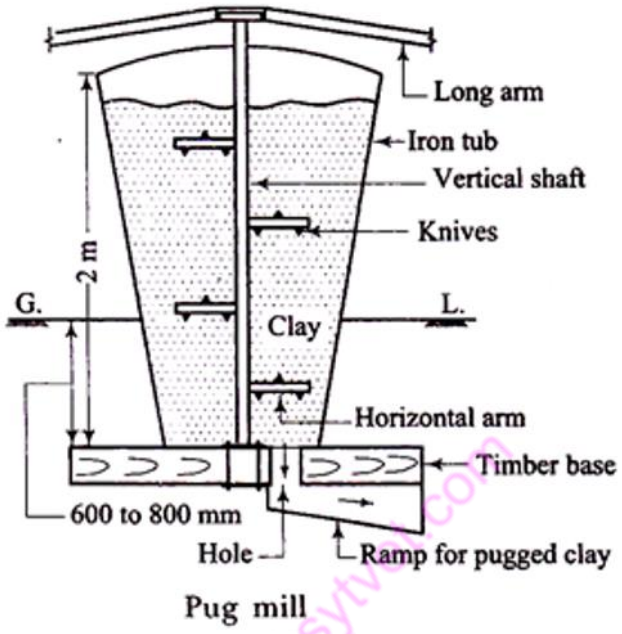
The provision is made in top cover to place clay inside the pug mill. A vertical shaft with horizontal arms is provided at the centre of iron tub. The small wedge-shaped knives of steel are fixed on horizontal arms.

The long arms are fixed at the top of vertical shaft to attach a pair of bullocks. The ramp is provided to collect the pugged clay. The height of pug mill is about 2 m. Its depth below ground is about 600 mm to 800 mm to lessen the rise of the barrow run and to throw out the tempered clay conveniently.

In the beginning, the hole for pugged clay is closed and clay with water is placed in pug mill from the top. When the vertical shaft is rotated or turned by a pair of bullocks, the clay is thoroughly mixed up by the actions of horizontal arms and knives and a homogeneous mass is formed.

The rotation of vertical shaft can also be achieved by using steam, diesel or electric power. When clay has been sufficiently pugged, the hole at the bottom of tub is opened out and the pugged earth is taken out from ramp by barrow i.e., a small cart with two wheels for the next operation of moulding. The pug mill is then kept moving and feeding of clay from top and taking out of pugged clay from bottom are done simultaneously.

If tempering is properly carried out, the good brick earth can then be rolled without breaking in small threads of 3 mm diameter.



https://www.engineeringenotes.com/engineering-materials-2/bricks/how-to-manufacture-bricks-brick-manufacturing-process-with-top-4-steps/46399

Fig. 30.Tempering process for large scale projects

➢ *Molding of Clay for brick Manufacturing:*

It is a process of giving a required shape to the brick from the prepared brick earth. Molding may be carried out by either hand(for small scale) or machines (large scale):

- **Hand molding -.**

  If manufacturing of bricks is on a small scale and manpower is also cheap then we can go for hand molding.

  The molds are in rectangular shape made of wood (fig.31)or steel (fi 32) which are opened at the top and bottom. The longer sides of molds are projected out of the box to serve it as handles. If we take durability in consideration steel molds are better than wooden molds.

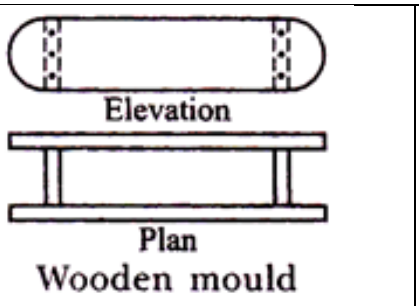


Fig . 31 wooden mould

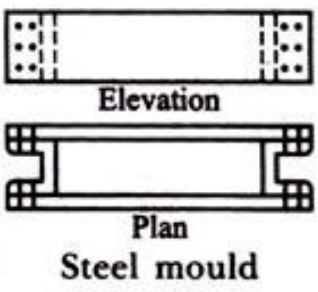


Fig. 32 Steel mould

https://www.engineeringenotes.com/engineering-materials-2/bricks/how-to-manufacture-bricks-brick-manufacturing-process-with-top-4-steps/46399

In hand molding again there are two types and they are:

- Ground molded bricks
- Table-molded bricks

- ***Ground molding process –***

(i) The ground is first made level and fine sand is sprinkled over it.
(ii) The mould is dipped in water and placed over the ground.
(iii) The lump of tempered clay is taken and it is dashed in the mould.
(iv) The clay is pressed or forced in the mould in such a way that it fills all the corners of mould.
(v) The extra or surplus clay is removed either by wooden strike or metal strike or frame with wire.
(vi) A strike is a piece of wood or metal with a sharp edge. It is to be dipped in water every time.
(vii) The mould is then lifted up and raw brick is left on the ground.
(viii) The mould is dipped in water and it is placed just near the previous brick to prepare another brick.
(ix) The process is repeated till the ground is covered with raw bricks.

NB-: A brick moulder can mould about 750 bricks per day with working period of 8 hours. When such bricks become sufficiently dry, they are carried and placed in the drying sheds.

The bricks prepared by dipping mould in water every time are known as the ***slop-moulded bricks***. The fine sand or ash may be sprinkled on the inside surface of mould instead of dipping mould in water. Such bricks are known as the ***sand-moulded bricks*** and they have sharp and straight edges.

The lower faces of ground moulded bricks are rough and it is not possible to place frog on such bricks.

A frog is a mark of depth about 10 mm to 20 mm which is placed on raw brick during moulding.

Frog serves two purposes:

(i) It indicates the trade name of the manufacturer.

(ii) In brickwork, the bricks are laid with frog uppermost. It thus affords a key for mortar when the next brick is placed over it.

- ***Table molding process –***
  This process is similar to ground molding process, but here the bricks on molded on stock boards nailed on the molding table of size 2m x 1m. The clay, mould, water pots, stock board, strikes and pallet boards are placed on this table. The bricks are moulded on the table and sent for the further process of drying.
  Ground molding is economical when compared to table molding.

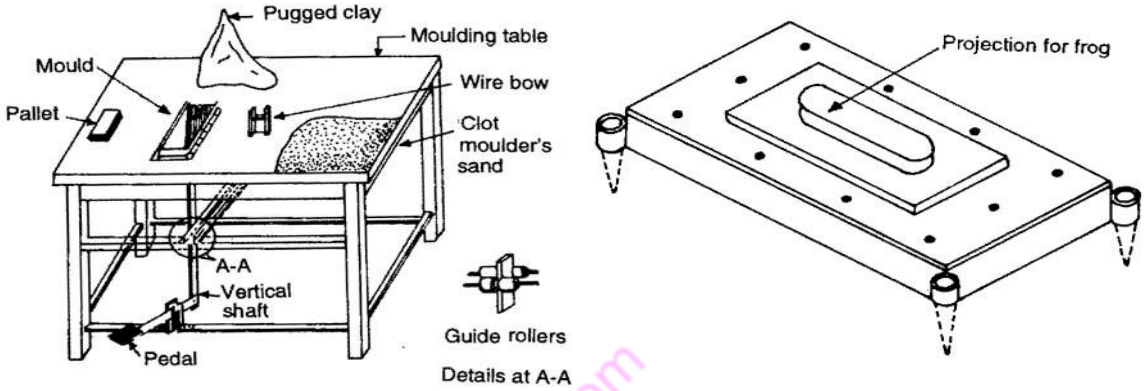


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Figure 31;- brick molding tables

❖ **Machine molding**
The bricks required are in large quantity, then machine molding is economical and also saves more time.
These machines are broadly classified in two categories:

- Plastic clay machines
- Dry clay machines

- ***Plastic Clay Machines***–
  These machines contain an opening in rectangular shape and when we place the tempered clay in to this machine it will come out through this opening. The pugged, stiffer clay is forced through a rectangular opening of brick size by means of an auger. Clay comes out of the opening in the form of a bar. The bricks are cut from the bar by a frame consisting of several wires at a distance of brick size. The arrangement is made in such a way that

strips of thickness equal to that of the brick are obtained. So, these are also called wire cut bricks. Now these raw bricks are ready for the drying process.
This is a quick and economical process.

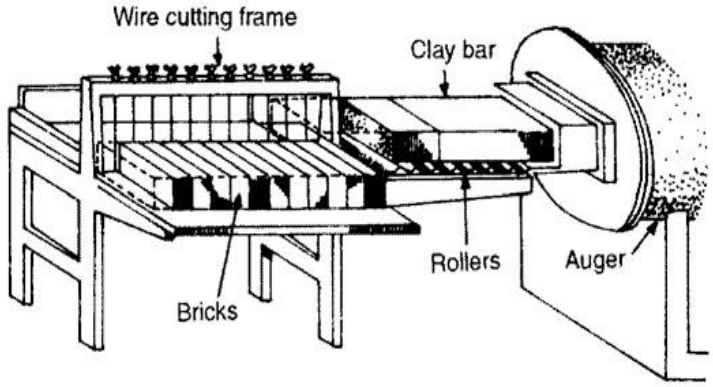

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Figure 22;- plastic molding table

- ***Dry press Machines–***
  In these machines, the strong clay is first converted into powder form. A small quantity of water is then added to form a stiff plastic paste. Such paste is placed in mould and pressed by machine to form hard and well-shaped bricks. These bricks are known as the pressed bricks and they do not practically require drying. They can be sent directly for the process of burning.
  The wire cut and pressed bricks have regular shape, sharp edges and corners. They have smooth external surfaces. They are heavier and stronger than ordinary hand-moulded bricks. They carry distinct frogs and exhibit uniform dense texture.

➢ Drying Process of Raw Bricks:

The aim of drying is to remove the moisture to control the shrinkage and save fuel and time during burning.
After molding process, the bricks contain some amount of moisture in it. So, drying is to be done otherwise they may cracked while burning. The drying of raw bricks is done by natural process.

(i) For drying, the bricks are laid longitudinally in stacks of width equal to two bricks.
(ii) A stack consists 8 to 10 tiers. The bricks in these stacks should be arranged in such a way that circulation of air in between the bricks is free.

(iii) The bricks are laid along and across the stock in alternate layers. All bricks are placed on edge. The bricks should be allowed to dry till they become leather hard or bone-dry with moisture content of about 2 per cent or so.
(iv) The period of drying may be 3 to 10 days. It also depends upon the weather conditions.
(v) The drying yards are also prepared on higher level than the normal ground for the prevention of bricks from rain water.
(vi) In Some situations artificial drying is adopted under special dryers or hot gases.

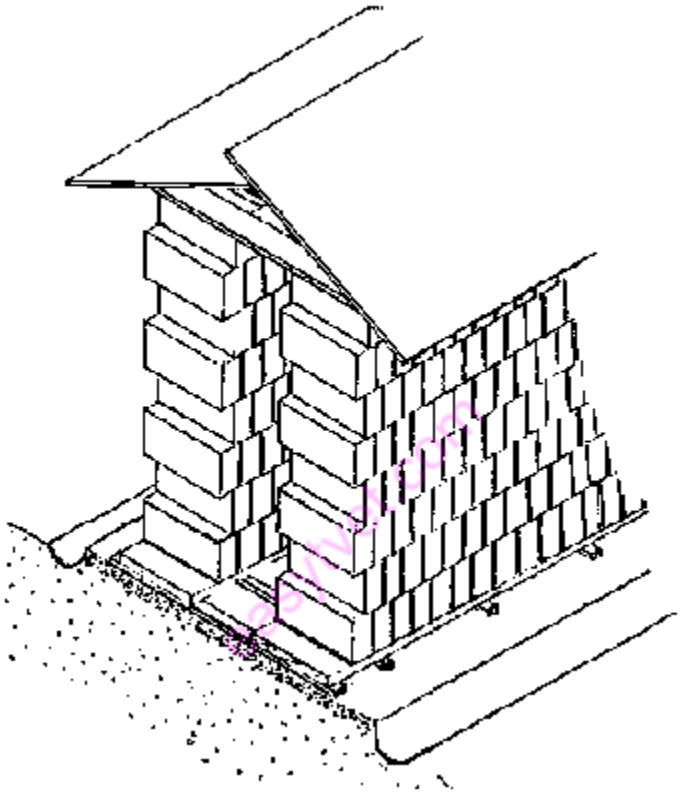

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Fig 31. Natural method of drying bricks covered by drying hack

➢ Burning of Bricks

After the process of moulding and drying, bricks are burnt in kilns to impart hardness, strength and to increase the density of the brick.
The bricks should be burnt properly. If bricks are over-burnt, they will be brittle and hence break easily. If they are under-burnt, they will be soft and hence cannot carry loads.
Some physical and chemical changes take place in the burning of bricks. Heating brick to about 640°C produces only physical changes. If a brick is heated up to 700-

1,000°C, it undergoes chemical changes. During this reaction, the materials present in brick alumina and silica fuse together to make the brick strong and stable to prevent from cracking and crumbling.

❖ **Chemical Changes which take place during the Burning process of clay bricks**

At least three chemical changes are known to take place in the brick-earth during the burning process: (i) dehydration, (ii) oxidation, and (iii) vitrification.

(i) Dehydration-

The Free water which has been retained in the pores of the clay after drying is driven off by heating the bricks to the temperature range of 425 – 750° C. and the clay loses its plasticity some of the carbonaceous matter is burnt. Bricks heated to this temperature lose all the free water and most of the water of crystallization. A portion of Sulphur is distilled from pyrites. Hydrous minerals like ferric hydroxide are dehydrated. The carbonate minerals are more or less decarbonized.

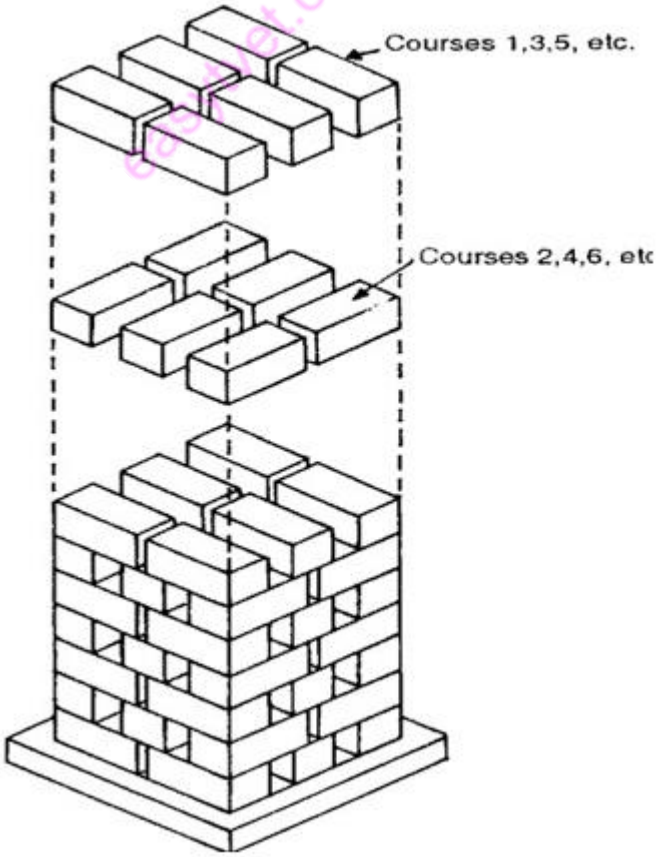

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Figure 32;- dehydration of bricks

(ii) Oxidation period-

It also starts within the above range or temperature and is completed at about 900°C. All the organic matter in the brick-earth gets oxidized; carbon and sulphur are eliminated as oxides.

The fluxes (lime, magnesia, and iron) also become reactive at this temperature. The brick acquires the red colour due to oxidation of iron in the clays.

Remainder of carbon is eliminated and the ferrous iron is oxidized to the ferric form.

The removal of Sulphur is completed only after the carbon has been eliminated

(iii) Vitrification

Is the extreme reaction that takes place from 900°C to 1100°C or so. The constituents of brick clay, that is alumina and clay, start softening in the presence of fluxes and getting bound together firmly.

This is the change which makes a brick a strong and hard unit. But when the brick is heated to the extreme temperature of vitrification, the fluxes may actually cause considerable softening of the essential components of the brick earth.

i. ***Incipient vitrification*** –

The clay has softened sufficiently to cause adherence but not enough to close the pores or cause loss of space—on cooling the material cannot be scratched by the knife

ii. ***Complete vitrification*** –

More or less well-marked by maximum shrinkage.

iii. ***Viscous vitrification –***

Produced by a further increase in temperature which results in a soft molten mass, a gradual loss in shape, and a glassy structure after cooling.

❖ **Methods of burning.**

The burning of bricks is done either in clamps or in kilns.

(i) Burning in clamp-

The clamps are temporary structures and they are adopted to manufacture bricks on a small scale to serve a local demand or a specific purpose.

The bricks and fuel are placed in alternate layers. The amount of fuel is reduced successively in the top layers. Each brick tier consists of 4–5 layers of bricks. Some space is left between bricks for free circulation of hot gasses.

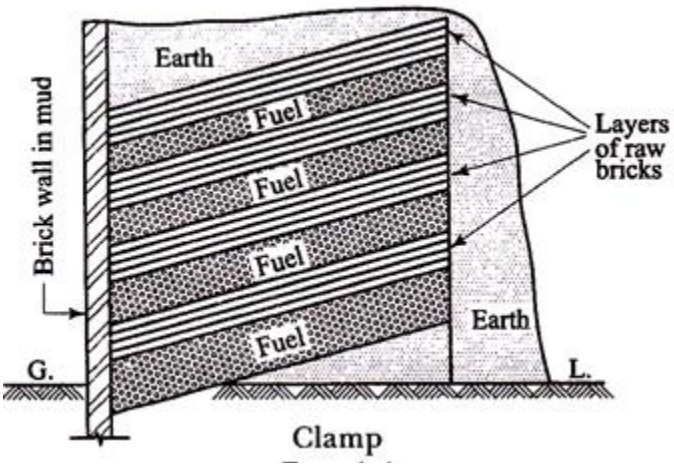

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fig. 32. Typical Clamp

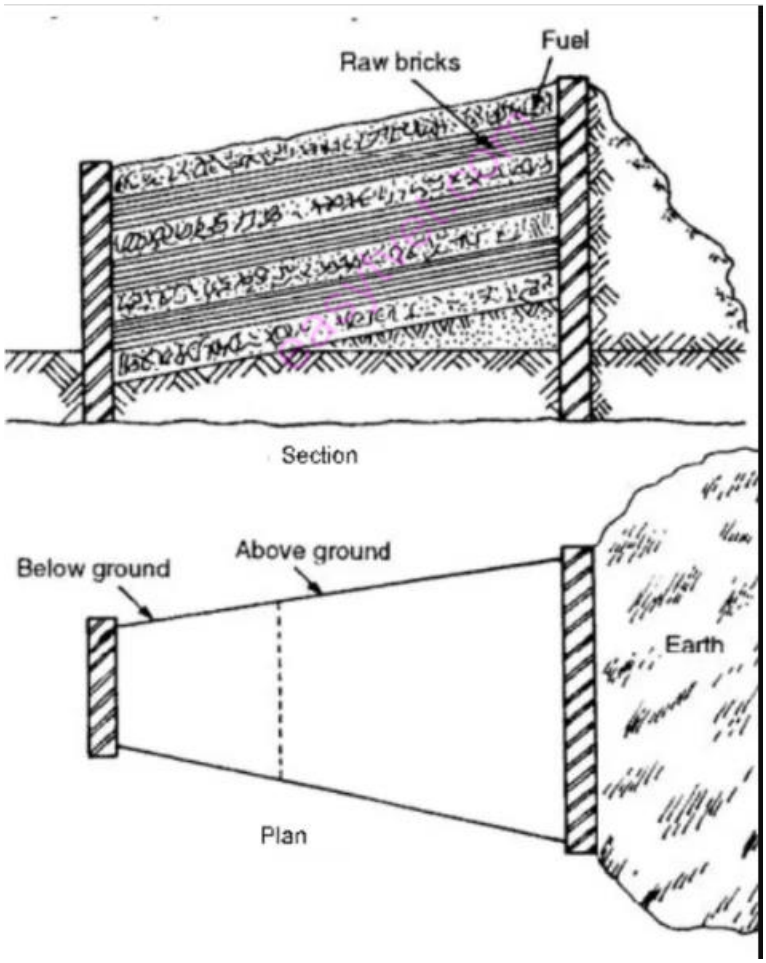

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fig . 33.Burning in Clump

- ***Clamp Construction Procedure:***

(i) A piece of ground is selected. Its shape in plan is generally trapezoidal. The floor of clamp is prepared in such a way that short end is slightly in the excavation and wider end is raised at an angle of about 15° from ground level.

(ii) The brick wall in mud is constructed on the short end and a layer of fuel is laid on the prepared floor. The fuel may consist of grass, cow dung, litter, husks of rice or ground nuts, etc. The thickness of this layer is about 700 mm to 800 mm. The wood or coal dust may also be used as fuel.

(iii) A layer, consisting of 4 or 5 courses of raw bricks, is then put up. The bricks are laid on edges with small spaces between them for the circulation of air.

(iv) A second layer of fuel is then placed and over it, another layer of raw bricks is put up. Thus alternate layers of fuel and raw bricks are formed. The thickness of fuel layer gradually decreases as the height of clamp increases.

(v) The total height of a clamp is about 3 m to 4 m. When nearly one-third height is reached, the lower portion of the clamp is ignited. The object for such an action is to burn the bricks in lower part when the construction of upper part of clamp is in progress.

(vi) When clamp is completely constructed, it is plastered with mud on sides and top and filled with earth to prevent the escape of heat. If there is any sudden and violent outburst of fire, it is put down by throwing earth or ashes.

(vii) The clamp is allowed to burn for a period of about one to two months.

(viii) It is then allowed to cool for more or less the same period as burning.

(ix) The burnt bricks are then taken out from the clamp.

- ***Advantages of Clamp Burning:***
  - The burning and cooling of bricks are gradual in clamps. Hence the bricks produced are tough and strong.
  - The burning of bricks by clamps proves to be cheap and economical.
  - No skilled labour and supervision are required for the construction and working of clamps.
  - The clamp is not liable to injury from high wind or rain.
  - There is considerable saving of fuel.
- ***Disadvantages of Clamp Burning:***
  - The bricks are not of regular shape. This may be due to the settlement of bricks when fuel near bottom is burnt and turned to ashes.
  - It is a very slow process.
  - It is not possible to regulate fire in a clamp once it starts burning and the bricks are liable to uneven burning.
  - The quality of bricks is not uniform. The bricks near the bottom are over-burnt and those near sides and top are under-burnt.

(ii) Kiln burning –

A kiln is a large oven which is used to burn bricks.They are permanent structures and they are adopted to manufacture bricks on a large scale.

The kiln used for burning bricks may be of the following types :

(i) Intermittent kilns

(ii) Continuous kilns.

(a) Intermittent kilns–

These kilns are intermittent in operation which means that they are loaded, fired, cooled and unloaded. Such kilns may be either rectangular or circular in plan. They may be over-ground or underground.

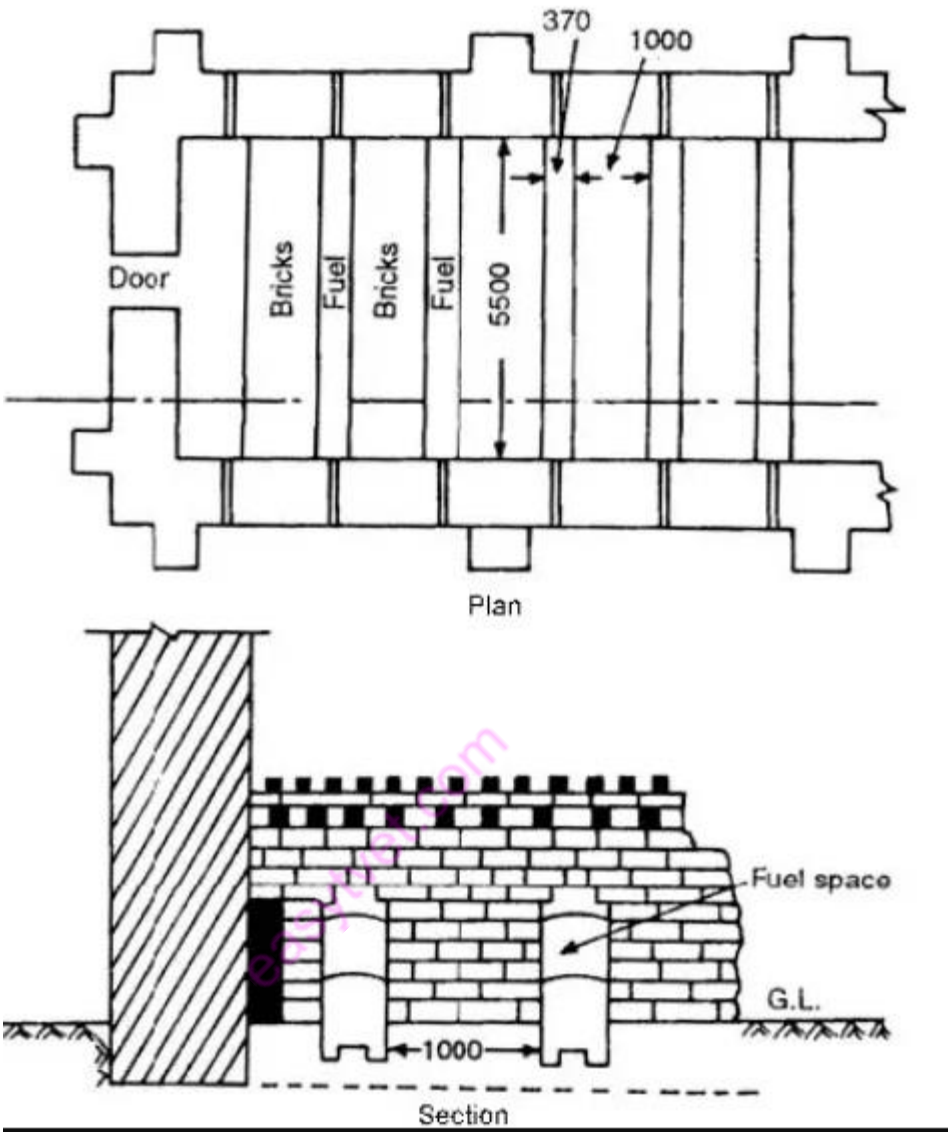
They are classified in two ways:

(i) Intermittent up-draught kilns

(ii) Intermittent down-draught kilns.

❖ **Intermittent up-draught kilns:**

These kilns are in the form of rectangular structures with thick outside walls. The wide doors are provided at each end for loading and unloading of kilns. The flues are channels or passages which are provided to carry flames or hot gases through the body of kiln. A temporary roof may be installed of any light material. Such roof gives protection to the raw bricks from rain while they are being placed in position. This roof is to be removed when the kiln is fired.



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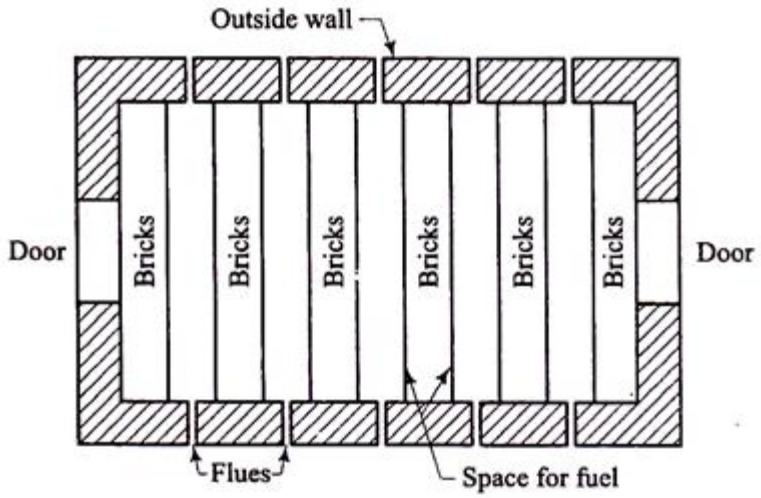
- fig. 34. Intermittent up-draught kilns:



Intermittent kiln

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fig. 33. The plan of a typical intermittent up-draught kiln.

https://www.thesprucecrafts.com/what-kind-of-kiln-is-it-2746127

fig. 34. Sectional view of an intermittent up-draught kiln.

- ***The working of the kiln is as follows:***
  - (i) The raw bricks are laid in rows of thickness equal to 2 to 3 bricks and of height equal to 6 to 8 bricks. A space of about 2 bricks is left between adjacent rows. This space is utilized for placing fuel.
  - (ii) The fuels are filled with brushwood which takes up a fire easily. The interior portion is then filled with fuel of bigger size.
  - (iii) An arch like opening is formed by projecting 4 to 5 rows of bricks. The projection of each row is about 30 mm to 40 mm.

(iv) The loading of kiln with raw bricks is then carried out. The top course is finished with flat bricks. Other courses are formed by placing bricks on edge.

(v) The end doors are built up with dry bricks and are covered with mud or clay.

(vi) The kiln is then fired. The fire can be regulated by opening or closing the iron sheet doors of the fire holes and by controlling the supply of fuel. The progress of burning at any instant can be seen through these holes. For the first three days, the firing is kept slow by proper manipulation of flues. The strong fire is maintained for a period of 48 to 60 hours. The draught rises in the upward direction from bottom of kiln and brings about the burning of bricks.

(vii) The kiln is allowed to cool down gradually for at least seven days and the bricks are then taken out.

(viii) The procedure is then repeated for the next burning of bricks. The bricks manufactured by the intermittent up-draught kilns are better than those prepared by clamps.

➢ ***But such kilns have the following disadvantages:***

- The quality of burnt bricks is not uniform. The bricks near bottom are over-burnt and those near top are under-burnt.
- The supply of bricks is not continuous.
- There is wastage of fuel heat as kiln is to be cooled down every time after burning.

❖ **Intermittent Down-Draught Kilns:**

These kilns are rectangular or circular in shape. They are provided with permanent walls and closed tight roof. The floor of the kiln has openings which are connected to a common chimney stack through flues. The working of this kiln is more or less similar to the up-draught kiln.

But it is so arranged in this kiln that hot gases are carried through vertical flues upto the level of roof and they are then released. These hot gases move downward by the chimney draught and in doing so, they burn the bricks.

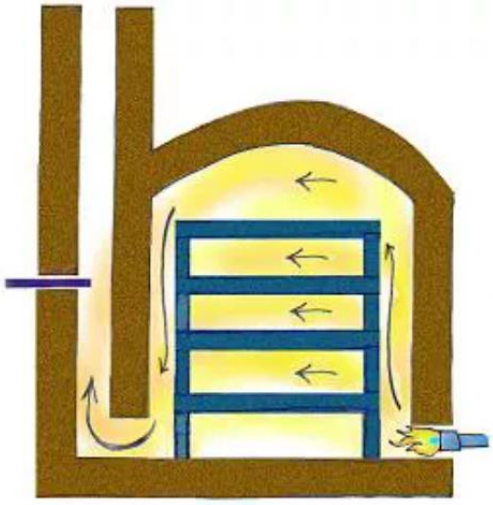

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fig. 35. Sectional view of an intermittent Down -draught kiln.

- ***Following advantages are claimed for the intermittent down-draught kilns:***
  - The bricks are evenly burnt.
  - The performance of this kiln is better than that of up-draught kiln.
  - There is close control of heat and hence such kilns are useful for burning structural clay tiles, terra-cotta, etc.

(b) Continuous kilns

These kilns are continuous in operation. This means that loading, firing, cooling and unloading are carried out simultaneously in these kilns. There are various types of the continuous kilns.

Following three varieties of continuous kilns will be discussed:

(i) Bull's trench kiln
(ii) Hoffman's kiln
(iii) Tunnel kiln.

(i) Bull's Trench Kiln:

This kiln may be of rectangular, circular or oval shape in plan. Fig. 34 shows a typical Bull's kiln of oval shape in plan.

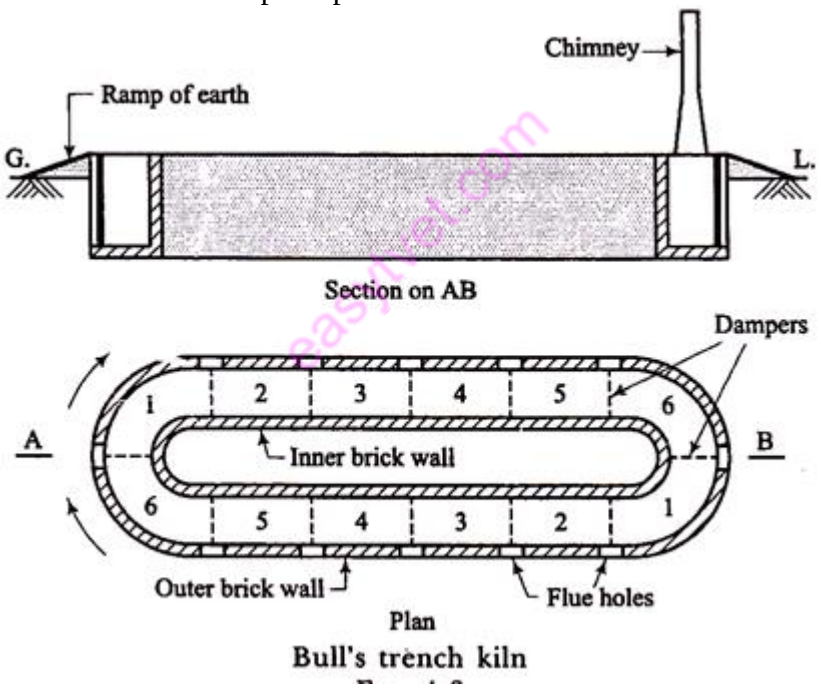

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fig. 34 Bull's Trench Kiln

As the name suggests, the kiln is constructed in a trench excavated in ground. It may be fully underground or partly projecting above ground.

In latter case, the ramps of earth should be provided on outside walls. The outer and inner walls are to be constructed of bricks. The openings are generally provided in the outer walls to act as flue holes. The dampers are in the form of iron plates and they are used to divide the kilns in suitable sections as shown in fig. 34. This is the most widely used kiln in India and it gives continuous supply of bricks.

The bricks are arranged in sections. They are arranged in such a way that flues are formed. The fuel is placed in flues and it is ignited through flue holes after covering top surface with earth and ashes to prevent the escape of heat. The flue holes are provided in sufficient number on top to insert fuel when burning is in progress. Usually the two movable iron chimneys are employed to form draught. These chimneys are placed in advance of section being fired. Hence the hot gases leaving the chimneys warm up the bricks in next section. Each section requires about one day to burn.

When a section has been burnt, the flue holes are closed and it is allowed to cool down gradually. The fire is advanced to the next section and the chimneys are moved forward as shown by arrows in fig. 34. The Bull's trench kiln is working continuously as all the operations — loading, burning, cooling and unloading are carried out simultaneously.

Fig. 34 shows Bull's kiln with two sets of sections. The two pairs of chimneys and two gangs of workers will be required to operate this kiln. A tentative arrangement for different sections may be as shown in table 1

Section	Arrangement
1	Loading
2	Empty
3	Unloading
4	Cooling
5	Burning
6	heating

Table 1

(ii) **Hoffman's Kiln:**

This kiln is constructed over-ground and hence it is sometimes known as the flame kiln. Its shape is circular in plan and it is divided into a number of compartments or chambers. As a permanent roof is provided, the kiln can even function during rainy season.

Fig. 35 shows plan and section of the Hoffman's kiln with 12 chambers.

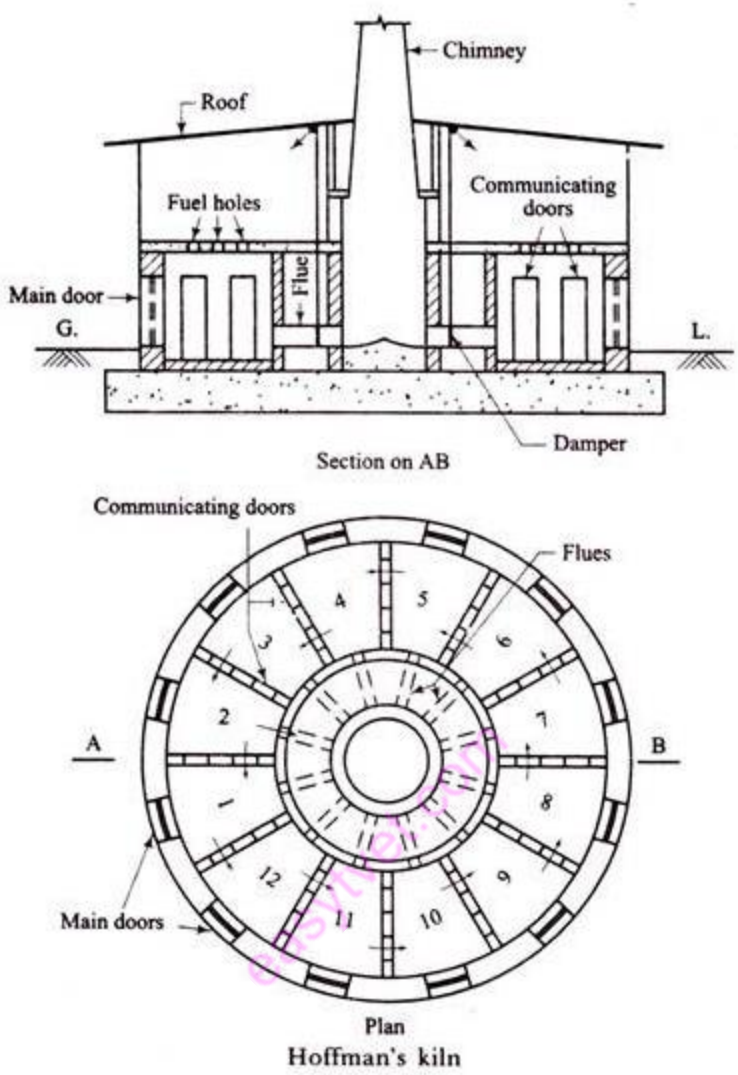

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fig.34 Hoffman's kiln

Each chamber is provided with the following:

- A main door for loading and unloading of bricks,
- Communicating doors which would act as flues in open condition,
- A radial flue connected with a central chimney, and
- Fuel holes with covers to drop fuel, which may be in the form of powdered coal, into burning chambers.

The main doors are closed by dry bricks and covered with mud, when required. For communicating doors and radial flues, the dampers are provided to shut or open them. In the normal condition, only one radial flue is connected to the chimney to establish a draught.

In this type of kiln, each chamber performs various functions in succession, namely, loading, drying, burning, cooling and unloading.

As an illustration, 12 chambers shown in fig. 4-7, may be functioning as follows:
Chamber 1 — Loading
Chambers 2 to 5 — Drying and pre-heating
Chambers 6 and 7 — Burning
Chambers 8 to 11 — Cooling
Chamber 12 — Unloading
With the above arrangement, the circulation of the flue gas will be as shown by arrows in fig. 4-7. The cool air enters through chambers 1 and 12 as their main doors are open. After crossing the cooling chambers 8 to 11, it enters the burning section in a heated condition. It then moves to chambers 2 to 5 to dry and pre-heat the raw bricks. The damper of chamber 2 is in open condition and hence it escapes into atmosphere through chimney.

The initial cost of installing this kiln is high, but it possesses the following advantages:

- The bricks are burnt uniformly, equally and evenly. Hence the high percentage of good quality bricks can be produced.
- It is possible to regulate heat inside the chambers through fuel holes.
- The supply of bricks is continuous and regular because of the fact that the top of kiln is closed and it can be made to work during the entire year.
- There is considerable saving in fuel due to pre-heating of raw bricks by flue gas. Thus, the hot gases are fully utilized in drying and pre-heating the raw bricks.
- There is no air pollution in the locality because the exhaust gases do not contain black smoke or coal dust particles.

The capacity of the kiln will depend upon the dimensions of chambers. If each chamber is of about 11 m length, 4.50 m average width and 2.50 m height, it will contain about 25000 bricks. Hence, if it is so arranged that one chamber is unloaded daily, such a kiln will manufacture about 25000 bricks daily or about 8 to 9 million bricks annually. The quantity of coal dust required for burning one lakh of bricks is about 120 to 150 kN.
It may be noted that in case of Bull's trench kiln and Hoffman's kiln, the chambers are zoned in accordance with the brick-processing stages, namely, loading, drying, preheating, burning, cooling and unloading. The source of fire and other zones are moving continuously along the channel of kiln while the bricks in process remain stationary.
Table 4-2 shows the comparison of Bull's trench kiln and Hoffman's kiln with respect to some important items.

COMPARISON BETWEEN BULL'S TRENCH KILN AND HOFFMAN'S KILN

No.	Item	Bull's trench kiln	Hoffman's kiln
1.	Burning capacity	About 3 lakhs in 12 days.	About 40 lakhs in one season.
2.	Continuity of working	It stops functioning during monsoon as it is not provided with a permanent roof.	It functions all the year round as it is provided with a permanent roof.
3.	Cost of fuel	High as consumption of fuel is more.	Low as consumption of fuel is less.
4.	Drying space	It requires more space for drying of bricks.	It requires less space for drying of bricks.
5.	Initial cost	Low	High
6.	Nature	It is semi-continuous in loose sense.	It is perfectly continuous.
7.	Popularity	More popular because of less initial cost.	Less popular because of high initial cost.
8.	Quality of bricks	Percentage of good quality bricks is small.	Percentage of good quality bricks is more.
9.	Suitability	Suitable when demand of bricks in monsoon is not substantial.	Suitable when demand of bricks is throughout the year.

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Table 2

iii) Tunnel Kiln:

This type of kiln is in the form of tunnel which may be straight, circular or oval in plan. It contains a stationary zone of fire. The raw bricks are placed on trolleys which are then moved from one end to the other end of tunnel.

The raw bricks get dried and pre-heated as they approach zone of fire. In zone of fire, the bricks are burnt to the required degree and they are then pushed forward for cooling. When bricks are sufficiently cooled, they are unloaded.

This kiln proves to be economical when bricks are to be manufactured on a large scale. As temperature is under control, uniform bricks of better quality are produced.

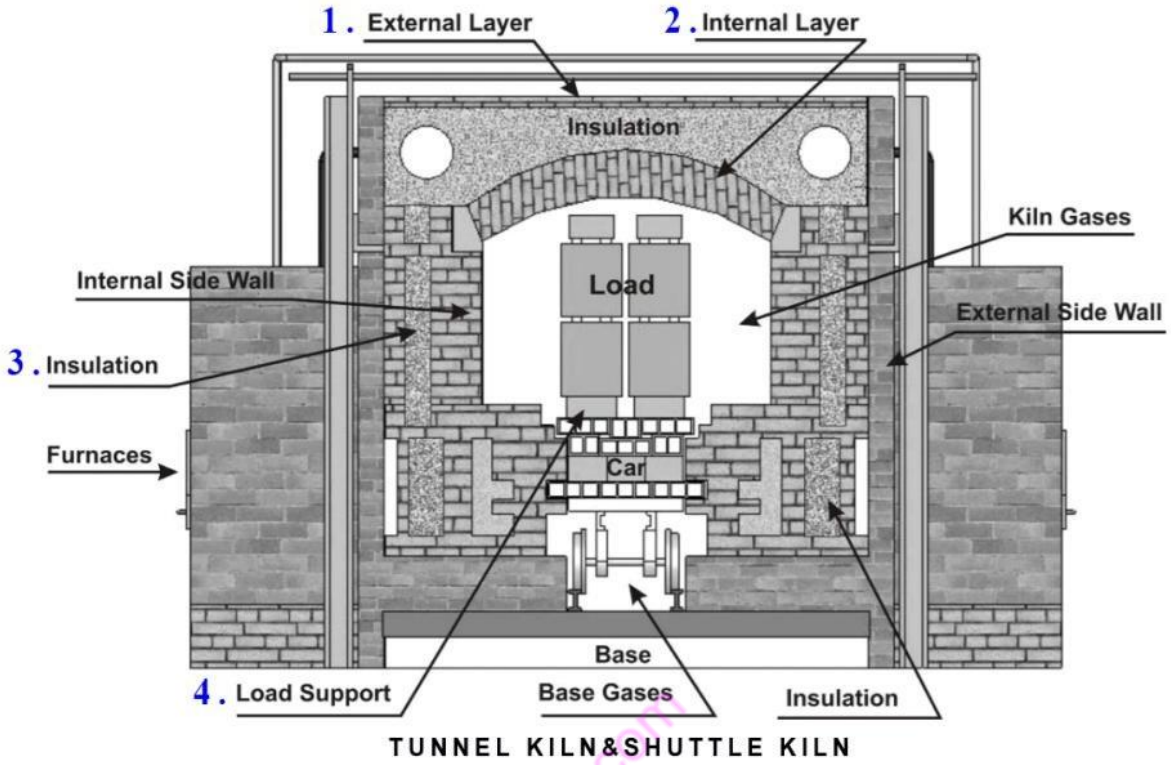

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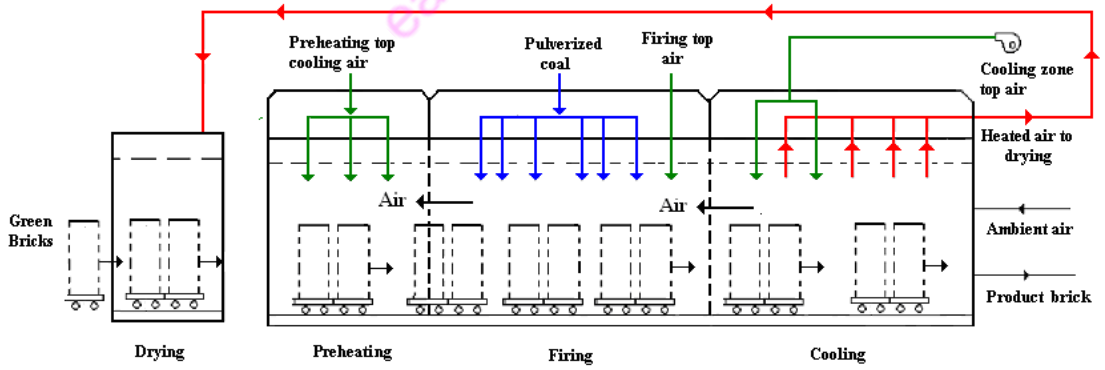
fig. 35 Tunnel Kiln



https://www.researchgate.net/figure/Schematic-representation-of-the-tunnel-kiln_fig1_288044522

Fig. 36 Schematic representation of the tunnel kiln.

(iii) Cooling:

In this stage of manufacturing of bricks, The burnt bricks are placed for some time to be cooled before using it in the construction.

c) CONCRETE

Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time.

Concrete is the most widely used building material in the construction industry. Freshly mixed concrete before set is known as wet or green concrete whereas after setting and hardening it is known as set or hardened concrete.

❖ ***Components of concrete:-***

- ***Cement-***

  cement is the fine powder that forms the "paste" that holds the aggregate together. Cement cures or hardens through the chemical reaction of hydration when mixed with water.

  The cement used should have a minimum compressive strength at different age. The particles of calcium-silicate hydrates form an interlocking network which is a 'gel'. The gel is the heart of the concrete and is a porous mass

- ***Course Aggregates –***

  This is usually gravel and provides the bulk of the compressive strength. Course aggregate can also include chunks of metal to increase the density .

  Aggregates constitute nearly 70–75 per cent of the total volume of concrete. For heavy weight concrete of density exceeding 3,200 kg/m3 material such as crushed barytes, limonite, iron ore, steel punching or small castings, with sp. gr. of 4.2, 4.75, 4 to 5 and 7.8 respectively are used as aggregate

- ***Fine Aggregates-***

  sand is used to fill in the spaces between the course aggregate.

  The smaller the maximum size of aggregate the greater the proportion of fine aggregate needed for concretes of identical cement contents and workability

- ***Water –***

  required primarily for hydration of cement and to give fluidity to the plastic mass. Water should be clean and free from impurities

- ***Admixtures –***

  There are many different kinds of additives that can be used to adjust properties of the concrete. Soap can be used to make air- entrained concrete which resists cracking in freezing climates. Some additives shorten the curing time, some make the concrete easier to work. Fiberglass is sometimes used to increase the strength. Based on the properties admixture imparts to the concrete, a selection can be done and the manufacturer's instructions followed for its method of use

❖ ***Concreting process:***

i) **Batching –**

refers to the process of measuring different concrete materials. These include cement, course aggregate (blue stone, etc), sand and water.

Batching can be done in two ways ;-

a) Volume batching
b) Wight batching

In volume batching , the measurements of concrete materials are taken by volume and the other hand ,the measurements are taken by weight in weight batching.

ii) **Mixing** –

the selected materials are mixed thoroughly to the required proportions. It's done until the resultant concrete paste has a uniform consistency and colour. In mixing of concrete, hand mixing and machine mixing are the two methods commonly used.

iii) **Transporting** –

Once the mixing process is complete, the concrete is transported to your site. Concrete can be transported to the site location in two ways:

- Manual Transportation.
- Mechanical Transportation.

In the truck, the concrete is kept at the correct wetness and continually rotates to prevent it setting. At the site, the concrete is poured directly into the formwork, transported by wheelbarrows or pumped up via large cranes and concrete hoses to get it into tricky locations.

iv) **Compaction & Leveling** –

Once the concrete has been evenly distributed into the formwork, the process of compaction begins. The aim is to eliminate air bubbles to increase the strength of the concrete. Screeding is then done, which is essentially a levelling process using large, straight edges that scrape across and flatten the surface. It is at this point, the desired concrete finishing effect can be applied.

v) **Curing –**

We then keep the concrete at an optimum moisture level for a certain time period, depending on the atmospheric conditions. This is required to complete the hydration process of the concrete, resulting in a high quality and long lasting concrete job.

❖ ***Characteristics of well mixed concrete***

- Concrete should be of uniform color.
- All concrete materials like cement, fine aggregates, coarse aggregates and water should be homogeneously mixed.
- Cement paste should cover all the surface of the aggregate.
- Segregation or bleeding of concrete should not occur after the concrete mixing.

❖ ***Methods of mixing concrete***

- **Hand Mixing of Concrete –**
  It is the process of mixing the ingredients of the concrete manually. It sis used only for small works where the concrete requirement is less and quality control is less important.

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Figure 37;- hand mixing of concrete

- **Machine Mixing of Concrete –**
  It is the process of mixing the ingredients of the concrete with a concrete mixer machine. It is highly effective for fulfilling the demands of short mixing time, optimum consistency and homogeneous quality of concrete.
  - **The Process of Machine Mixing of Concrete:**
    (i) First of all, wet the inner surfaces of the drum of concrete mixer.
    (ii) Placed Coarse aggregates in the mixer first, followed by sand and then cement.
    (iii) Mix the materials in the dry state in the mixing machine. Normally it should be 1.5 to 3 minutes.
    (iv) Gradually add the correct quantity of water while the machine is in motion, after proper mixing of dry materials. Do not add more water than required. It is not advisable as it reduces strength.
    (v) Mix concrete for a minimum of two minutes in the drum after adding the water,

    Note:

    If there is any segregation of concrete after unloading from the mixer, then remix the concrete.

  - **Precautions to be Taken While Machine Mixing of Concrete:**

- Concrete mixer machine must be wet before use.
- Take care of mixing time, speed and numbers of revolution of mixer drum as per the recommendation of the manufacturers of the mixer machine.
- Concrete should be used within 30 minutes after mixing and discharged by the concrete mixer.
- Clean thoroughly the interior surface of the mixer drum after discharging one batch of concrete if your mixing is batch type. If not, lumps of hardened concrete from the mix of previous batch may form a part of the subsequent batch and deteriorate the quality of concrete.
- It is necessary to clean the concrete mixer after fixed intervals. If your mixing is of a continuous type.
- Inspect the inner portion of the concrete mixer carefully at regular intervals to check for damages, shatter or corrosion.

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.toolstoday.co.uk%2Fbelle-premier-100xt-electric-start-mobile-cement-mixer&psig=AOvVaw37dVQXpssViZIBHUgfeqO7&ust=1626374574140000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCJDMyMWb4_ECFQAAAAAdAAAAABAH

Figure 38;- concrete mixer

- **Ready Mix Concrete –**

  Mixing of ready mixed concrete can be done either in automatic or semi-automatic batching plant.

  Ready Mix Concrete (RMC) is a specialized material in which the cement, aggregates and other ingredients are weighed and batched at a plant at a central location, then mixed either in a central mixer or in truck mixers, before being delivered to the construction site in condition ready for placing by the customer.

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Ffully-automatic-batching-plant-7869762897.html&psig=AOvVaw2fdXVPsU5jbNZki-ZpX9zH&ust=1626374930890000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCJDlm-qc4_ECFQAAAAAdAAAAABAD

Figure 39;- fully automatic batch plant

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.nilkanthmachinetools.com%2F&psig=AOvVaw2b67KzVmsGSyA7G2nIWGPm&ust=1626374978311000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLDWgIad4_ECFQAAAAAdAAAAABAD

Figure40;- semi automatic batch plant

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.boxley.com%2Fconcrete.html&psig=AOvVaw2wQ7rGDUW_4HdOL6Gwjo09&ust=1626374710870000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNiyspKc4_ECFQAAAAAdAAAAABAI

Figure 41;- delivery of ready concrete

- ✓ **Factors affect the method of concrete mixing:**
  - Location of the construction site with sufficient land for construction activities e.g. highly congested urban areas.
  - Available space for concrete batching and mixing and storage of aggregates.
  - Volume of concrete needed.
  - The construction schedule like the volume of concrete required per hour or per day.
  - Height at which concrete is to be placed.
  - Cost.

c) BUILDING MORTAR

- ❖ ***Definition:***

Mortar is a workable paste which hardens to bind building blocks such as stones, bricks, and concrete masonry units, to fill and seal the irregular gaps between them, spread the weight of them evenly, and sometimes to add decorative colors or patterns to masonry walls. Prepared from Portland cement or its varieties, sand and water.

❖ *Main Functions of Mortar in Construction:*

Mortar in construction is mainly needed for masonry work, plastering, and pointing. But it serves many significant functions:

- To bind the building units such as bricks, stones, etc. into a solid mass,
- Binds together bricks or stones.
- Provides strength to the structure.
- It offers cohesion or force between the structural unit.
- It serves as an important medium for uniformly distributing the forces through the structure.
- Imparts additional resistance and power against the rain dispersion and other such weathering agencies.
- It fills up empty joints in brick or stone masonry. Typically, a thin liquid mortar known as Grout is used for such purposes.
- To carry out pointing and plaster work on exposed surfaces of masonry,
- To form an even and soft bedding layer for building units,
- To form joints of pipes,
- To prepare moulds for coping, corbels, cornice, etc.,
- To serve as a matrix or cavity to hold coarse aggregates, etc.,
- To distribute uniformly the super incumbent weight from upper layer to lower layer of bricks or stones,
- To hide the open joints of brickwork and stonework,
- To fill up the cracks detected in the structure during maintenance process, etc.

https://gosmartbricks.com/everything-about-mortar-in-construction/

fig. 42 Cement sand mortar

NB;

Cement, lime and clay used as binding materials impart adhesive power and strength.

Sand is an adulterant, but increases the crushing strength of mortar and reduces shrinkage. When used in lime mortar, it assists the hardening of fat lime by allowing air to penetrate providing carbon dioxide for carbonization.

Surkhi is used for economy and for furnishing hydraulic properties to lime mortar.
Fly ash and cinders are used in lime mortar as fine aggregate in place of Surkhi.
Molasses or gur is mixed with fat lime mortar to increase its solubility hence crystalize easily.
Water in mortar lubricates the surfaces of aggregate, spreads the binding material uniformly so that it can fill the pores in the fine aggregate and cause hydration of cement and hydraulic lime.

❖ *Quality Of Good Mortar-*

It is crucial to appreciate the mortar's quality and how its ingredients affect performance. Let's understand the different qualities of a good mortar in construction:

(i) **Workability:**

One of the most important properties of plastic (a state where the mortar is fresh and not yet hardened) mortar is Workability. Few of the indications of workability are:

- Mortar easily spreads with the trowel.
- It supports the weight of the masonry units.
- It adheres to masonry surfaces (is sticky).
- It extrudes easily from the joint when the mason put on pressure to the unit.
- In addition to that, Workability of fresh mortar also refers to the comprehensive properties of mortar easy for construction and good for quality, counting mobility and water retention. Basically, a mortar with great mobility is easy to be paved evenly and thinly over the bricks and bonded with floors well.

(ii) **Strength:**

A mortar is said to be good in strength when it hardens. But again, the use of a good quality material in decent proportions actually lead to good strength mortar. Also, along with the mortar, the units of the overall structure also need to be of good quality only then the structure stands for a long period. Hence, when it comes to preparing a good strength mortar, sufficient cement content and well graded fine aggregate needs to be used. Also, water content needs to be just right, adding more or less than the required amount can adversely affect its strength quality.

(iii) **Water Retention:**

A great quality mortar's water retention capacity is very strong. A mortar should not drop its water content exclusively during transportation. If its water content is separated or lost from the mix, then it is very difficult for the mortar to harden and it also loses it strength. Also, the mortar is incapable of developing a strong bond when the surface without adequate water in it. Essentially, to enhance the water retention capacity of the mortar, several types of plasticizers are used.

❖ *Properties Of Good Mortar*

A mortar is considered truly good when it obeys the following mentioned properties:

- **Adhesive Properties** –
  To develop a strong bond with masonry units the mortar should possess adequate adhesive property.
- **Water Proof** –
  The mortar needs to be waterproof and it should be able to restrict water to enter through it in the external walls during the rainy seasons.
- **Durability** –
  It should be durable. It should be long-lasting; with that it means it should be able to withstand the continuous wear and tear.
- **Workability** –
  It should be easily workable. In a synopsis, workability of fresh mortar refers to the comprehensive properties of mortar easy for construction and good for quality, including mobility and water retention.
- **Strength** –
  A good mortar needs to develop designed stresses post hardening.
- **No Cracks** –
  It is easy for the mortar to get deformed when it bears constant loads and temperature changes. If it deforms critically, the quality of masonry and surface will decline and cause shrinkages and cracks. A good mortar is the one that doesn't crack near the joints, also it is able to maintain decent appearance for longer phases.
-
- **Less Setting Time** –
  A good mortar should take very less time to set, this ensures speedy construction.

❖ *Classification of mortars*

The mortars are classified on the basis of the following:

(a) Bulk density
(b) Kind of binding material
(c) Nature of application
(d) Special mortars.

(a) Bulk density:

According to the bulk density of mortar in dry state, there are two types of mortars:

(i) Heavy mortars
(ii) Lightweight mortars.

(i) Heavy Mortars:

The mortars having bulk density of 15 kN/m^3 or more are known as the heavy mortars and they are prepared from heavy quartzes or other sands.

(ii) Lightweight Mortars:

The mortars having bulk density less than 15 kN/m^3 are known as the lightweight mortars and they are prepared from light porous sands from pumice and other fine aggregates.

(b) Kind of Binding Material:

Factors to be considered when selecting the kind of binding material for mortar are:

- Expected working conditions,
- Hardening temperature,
- Moisture conditions, etc.

***According to the kind of binding material, the mortars are classified into the following five categories*:**

(i) *Lime mortar*
(ii) *Surkhi mortar*
(iii) *Cement mortar*
(iv) *Gauged mortar*
(v) *Gypsum mortar.*

➢ *Lime Mortar:*

Lime mortar is made by mixing lime, sand and water. In this type of mortar, the lime is used as binding material. Lime used for mortar may be fat lime or hydraulic lime.

- ***Fat lime:***

Fat lime has high calcium oxide content. Its hardening depends on loss of water and absorption of carbon dioxide from the atmosphere and possible recrystallization in due course. The fat lime shrinks to a great extent and hence it requires about 2 to 3 times its volume of sand. The lime should be slaked before use. This mortar is unsuitable for water-logged areas or in damp situations.

Slaked fat lime is used to prepare mortar for plastering,

- ***Hydraulic lime:***

Hydraulic lime contains silica, alumina and iron oxide in small quantities. When mixed with water it forms putty or mortar having the property of setting and hardening under water. For hydraulic lime, the proportion of lime to sand by volume is about 1:2 or so. This mortar should be consumed within one hour after mixing.

It possesses more strength and can be used in damp situations. The lime mortar has a high plasticity and it can be placed easily. It possesses good cohesiveness with other surfaces and shrinks very little. It is sufficiently durable, but it hardens slowly. It is generally used for lightly loaded above-ground parts of

buildings. Hydraulic lime is used for masonry construction and is most suitable for construction of chimneys and lightly loaded superstructure of buildings.

✓ Preparation of Lime Mortar:

- ***Manual mixing***
  (i) Lime and sand in required quantities are placed on an impervious floor or in a tank.
  (ii) The constituents are thoroughly mixed dry by turning them up and down with spades.
  (iii) Water is added and mixing is done again with spades till mortar of uniform color and consistency is obtained.

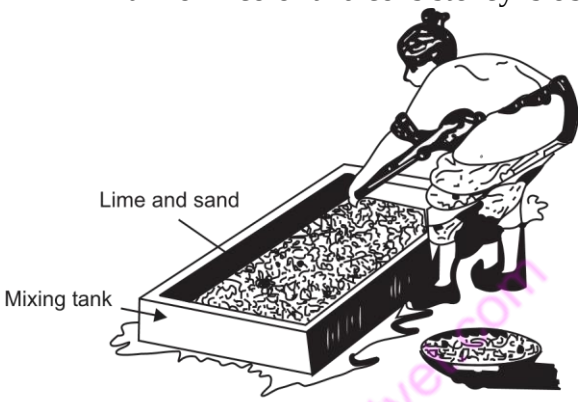

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Figure 43;- manual mixing

Lime is prepared under the following methods: -

(i) *Pounding:*
Lime is prepared by pounding, if quantity required is small or,

(ii) *Grinding*
If the required quantity is more.

Following are the two objects of pounding or grinding lime mortar:

(i) To crush the particles of un-slaked lime, if any, so as to ensure slaking; and
(ii) To make an intimate mixture of the whole mass so that no two grains of sand are without an intervening film of the binding material.

- ***Pounding:***

For pounding pits are formed in hard grands. The pounding is adopted for preparing small quantities of mortar. In this method,

(i) The pits of about 1.8 m long, 400 mm wide at bottom, 500 mm wide at top and 500 mm deep are formed in hard ground and provided with lining of bricks or stones at their sides and bottom.

(ii) The lime and sand are mixed in dry state and the mixture is then placed in pits.

(iii) A small quantity of water is added and four to five persons with heavy wooden pounders or beaters work on mortar.

(iv) They turn mortar up and down frequently.

(v) The required quantity of water is added at intervals.

(vi) The process is continued till uniform colour and desired consistency is achieved.

(vii) When desired consistency is achieved, the mortar from pits is taken out.

Preparation:

- ***Grinding:***

This is the better way of getting good mix. The grinding is adopted for preparing large quantities of mortar and to ensure a steady and continuous supply of mortar. In this method, the grinding mills are used to prepare mortar.

Mill mixing - Mills used for preparing lime mortars in undeveloped countries may be a chakki or ghanni run by bullock. **pan mill** is used in developed countries

These mills are of the following two types:

(*i) Bullock-driven grinding mill*

(ii) Power-driven grinding mill

.

- **Bullock- Driven Grinding Mill:**

✓ ***Description of a Bullock-driven grinding mill***

This is also known as the Ghani. Fig. 43 shows the details of a typical bullock-driven grinding mill. A circular trench of diameter about 6 m to 9 m and depth of about 400 mm is prepared. The width of the trench is about 300 mm or so to accommodate stone wheel with side margins of about 50 mm. A horizontal wooden shaft passes through stone wheel. One end of shaft is attached to the pivot and at the other end, the bullock is attached to cause the rotation of stone wheel. Bullock drive this wheel in the trench for grinding mortar.

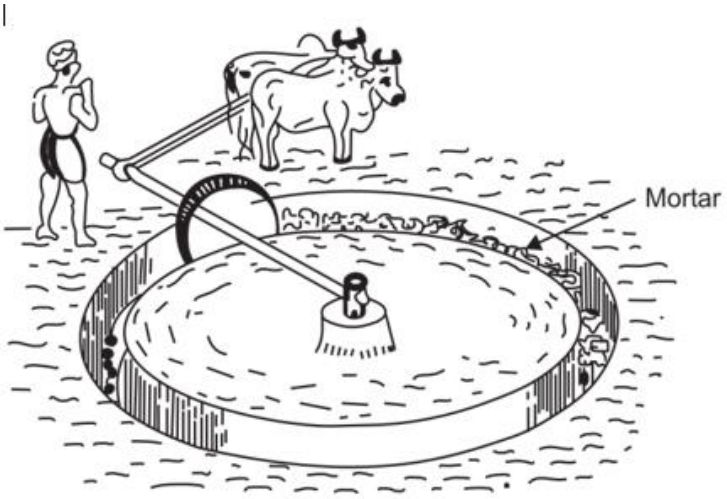

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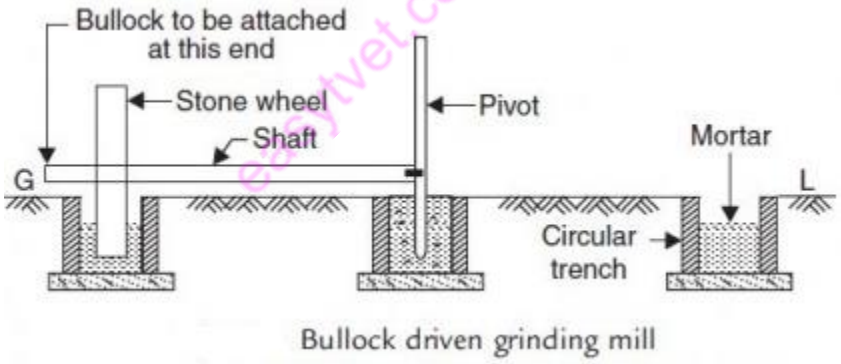
fig.44 -Bullock-driven grinding mill



https://www.civilengineeringx.com/mortars/lime-mortar/

fig.45 -Bullock-driven grinding mill

- ✓ ***Preparation of Lime mortar in a Bullock-driven grinding mill: -***
  - i. The lime and sand in required proportions are placed in the trench by shovels.
  - ii. The required quantity of water is added to bring proper consistency of the mortar and the bullock is allowed to take turns round the mill.
  - iii. A worker turns the mix up and down regularly.
  - iv. As bullock rotates, the lime and sand are intimately mixed by the grinding action of stone wheel.
  - v. In addition, they are also frequently turned with the help of spade.

Note:

To record the number of turns made by the bullock, an arrangement known as the Beale's tell-tale is provided at the pivot. It is in the form of a spindle with groove. A turn is indicated by the rise or fall of groove.
A normal Ghani can prepare about 1.70 m^3 of mortar at a time and it will require a period of about 6 hours to complete one cycle of operations.

- ***Power-Driven Grinding(Pan) Mill:***
  - ✓ ***Description of a power-driven grinding(pan) Mill.***

In this type of mill, the power is used to mix intimately lime and sand. Fig. 44 shows a typical power-driven grinding mill. It consists of a revolving pan of diameter about 1.80 m to 2.40 m. In this pan, two rollers are provided. The rollers are fixed. The pan is revolved either with the help of an oil engine or steam engine or electric power. In another variety, the pan is kept stationary and the rollers are moving.

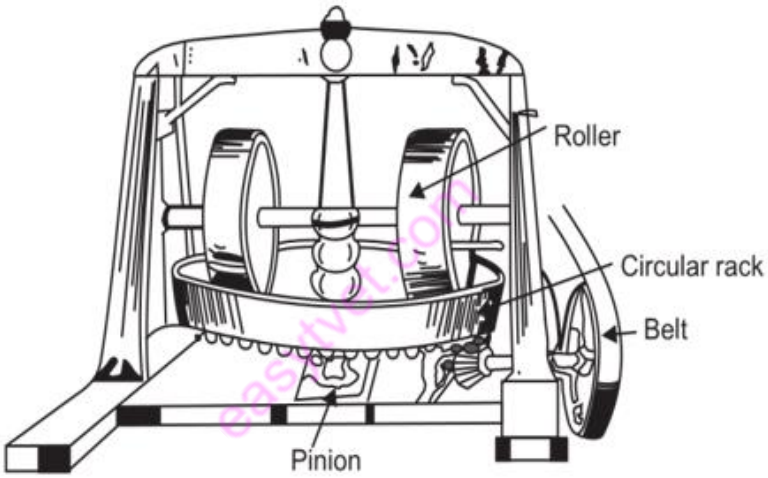


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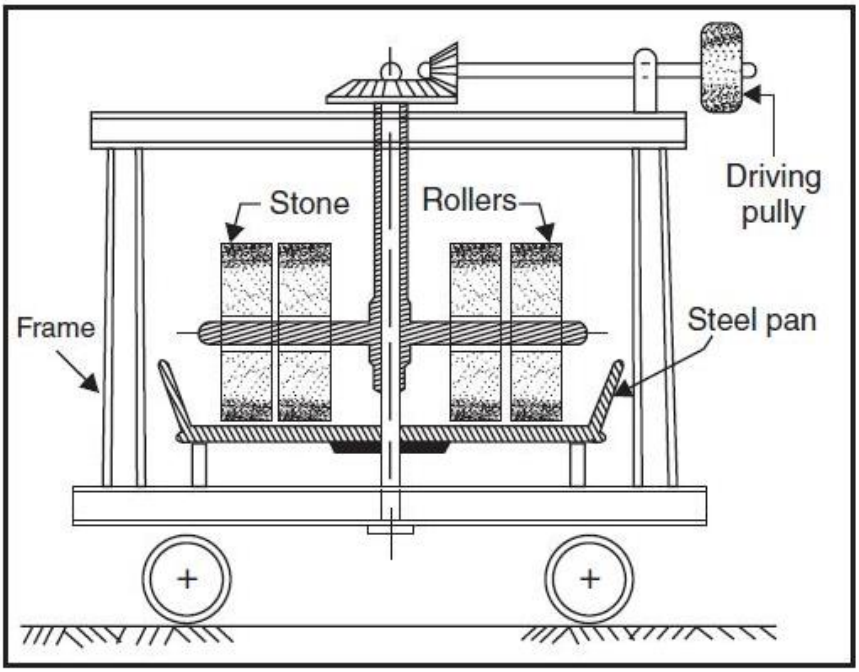
Fig. 46 Power driven grinding (Pan) mill.



https://www.civilengineeringx.com/mortars/lime-mortar/

Fig. 47 Power driven grinding (Pan) mill.

✓ ***Lime mortar Preparation in a power- driven grind mill:***

i. The lime and sand in required proportions are placed in pan.
ii. The required quantity of water is added and the pan is then revolved.
iii. During mixing process, quantity of water may be added gradually in case the initial amount of water is not enough.

Note:

This method of grinding lime mortar is quite efficient and it produces mortar of better quality. It also ensures steady and continuous supply of mortar.

✓ *Precautions to be taken when preparing lime mortar:*

Lime mortar or putty should be kept moist till use and in no case its drying is allowed.

The mortar made of hydraulic lime should be consumed within one day and that with fat lime within 2-3 days.

➢ *Surkhi Mortar:*

The powder of surkhi should be fine enough to pass BIS No. 9 sieve and the residue should not be more than 10% by weight.

The surkhi mortar is used for ordinary masonry work of all kinds in foundation and superstructure. But it cannot be used for plastering or pointing since surkhi is likely to disintegrate after some time.

- ***Preparation of Surkhi Mortar:***

Surkhi should be ground to pass through 4.75 mm sieve and about less than 15 per cent through 150 micron sieve.
It is prepared in the same way as lime mortar, with surkhi replacing sand.
It is prepared by using the mix of fat lime and surkhi instead of sand or or fat lime, surkhi and sand is decided and it is converted into a good paste by grinding in a mortar mill or by pounding.

- ***Cement Mortar:***

In this type of mortar, the cement is used as binding material. This mortar does not require pounding or grinding. Depending upon the strength required and importance of work, the proportion of cement to sand by volume varies from 1:2 to 1:6 or more. It should be noted that surkhi and cinder are not chemically inert substances and hence they cannot be used as adulterants with matrix as cement. Thus, the sand only can be used to form cement mortar. The proportion of cement with respect to sand should be determined with due regard to the specified durability and working conditions.
The cement mortar is used where a mortar of high strength and water-resisting properties is required such as underground constructions, water saturated soils, etc. Portland cement and blast furnace slag cement form excellent mortars for walls built with bricks, stones and large blocks.
Pozzolana Portland cement and Sulphate-resisting cement form mortar which are used for constructions exposed to aggressive and waste waters.

- ***Preparation of Cement Mortar:***

Small quantities of mortar are mixed manually or mechanical mixers may be used for large quantities.

- ✓ ***Manual mixing***

(i) Sand is sieved, cleaned with water to remove dirt and dust and dried.
(ii) The required ratio of dry sand is measured and then laid uniformly, on a watertight platform or steel trough.
(iii) The required cement ratio is measured and then laid over the sand and uniformly spread.
(iv) The whole mass is then thoroughly mixed in dry state twice or thrice with spades till it becomes uniform in color.
(v) A depression is then made in the middle of the mix and required quantity of water is added.
(vi) The dry mix from the sides is moved and placed on the edges of the depression formed till the water is completely absorbed by the mix.
(vii) The wet mix is then thoroughly mixed with spades to give a uniform consistency to the mortar.

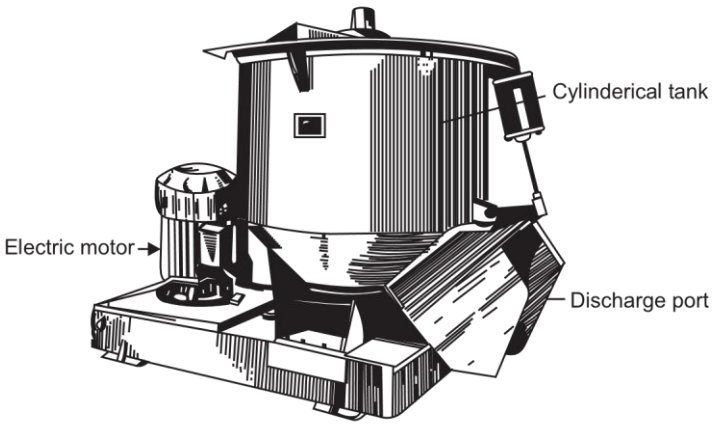


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Figure 48;- tubulent mortar mixer

- ***Precautions:***
  - Cement mortar should be of uniform and workable consistency.
  - It should be consumed within 30 minutes from the instant of adding water to the mix.
  - The bricks, stones and blocks should be fully saturated in water before laying.
  - The masonry and plastered or pointed surface should be kept completely wet by sprinkling water for at least 7 days.

- ***Effects of various substances on cement mortar:***
  - ***Alkaline water –***
    Neat cement paste may disintegrate by the combined chemical and mechanical action of waters containing salts
  - ***Oil and acids –***
    cured cement mortars are not affected by oils. Lean mortars may develop less strength after 7 days when partially immersed in oil than when ***moist***-cured for a month prior to immersion. The mortar surfaces soaked with oil show a marked reduction in abrasive resistance.
  - ***Sugar –***
    Up to 0.15 per cent of sugar added to cement delays the setting time and destroys the early strength. However, when added up to 2 per cent, it increases the strength at an age of 2 to 3 months. The action of sugar is attributed to the formation of a soluble calcium saccharate ($C_{12}H_{22}O_{11}.CaO + 2H_2O$)
  - ***Low and high temperatures –***
    The rate of setting of cement falls for temperature falling below 4.5°C. When the temperature falls below freezing the particles of cement in unset cement paste separate by the expansion of water
  - ***PreK-mixing and re-tempering –***

Only half of the cement grains are hydrated by water in ordinary cement paste.

- ***Gauged Mortar/Guarded/Lime-Cement:***

Lime-cement mortar/Guarded mortar/Guarded is made by mixing cement and lime.
To improve the quality of lime mortar and to achieve early strength, the cement is sometimes added to it. This process is known as the ganging. It makes lime mortar economical, strong and dense.
The usual proportion of cement to lime by volume is about 1:6 to 1:8. It is also known as the composite mortar or lime-cement mortar and it can also be formed by the combination of cement and clay. This mortar may be used for bedding and for thick brick walls.

- ***Preparation of Gauged Mortar:***
  - The lime mortar is prepared as shown above.
  - The required quantity of cement is then added and the ingredients are thoroughly turned up and down to cause intimate mixing.
- ***The advantages of lime-cement mortar are;***
  - increased water retentivity
  - workability
  - bonding properties
  - Frost resistance.
  - gives good and smooth plaster finish

- ***Gypsum Mortar:***

These mortars are prepared from gypsum binding materials such as building gypsum and anhydrite binding materials.

- ***Mud Mortar:***

They are the cheapest type of mortar prepared with locally available ingredients and are used for;
  - Masonry works.
  - Surfacing floors.
  - Plastering wall surfaces in low-cost houses.

NB; To improve resistance to rain water, the plastered surfaces are sometimes sprayed with bituminous material

Preparation:

(i) The top 150 to 200 mm layer of earth is removed and the clay nodules dug from the ground are wetted and allowed to mature for a day or two.
(ii) Some fibrous material such as cow dung is added which prevents the shrinkage cracks.
(iii) The ingredients are then kneaded well and mixed thoroughly.

(c) Nature of Application:

According to the nature of application, the mortars are classified into two categories:
(i) Bricklaying mortars
(ii) Finishing mortars.

(i) Bricklaying Mortars:

The mortars for bricklaying are intended to be used for brickwork and walls. Depending upon the working conditions and type of construction, the composition of masonry mortars with respect to the kind of binding material is decided.

(ii) Finishing Mortars:

These mortars include common plastering work and mortars for developing architectural or ornamental effects. The cement or lime is generally used as binding material for ordinary plastering mortar. For decorative finishing, the mortars are composed of suitable materials with due consideration of mobility, water retention, resistance to atmospheric actions, etc.

(d) Special Mortars:

Following are the various types of special mortars which are used for certain conditions:

(i) Fire-resistant mortar
(ii) Lightweight mortar
(iii) Packing mortar
(iv) Sound-absorbing mortar
(iv) X-ray shielding mortar.
(v) Damp proof mortar
(vi) Mortars for filling joints

(i) Fire-Resistant Mortar:

This mortar is prepared by adding aluminous cement to the finely crushed powder of fire-bricks. The usual proportion is 1 part of aluminous cement to 2 parts of powder of fire-bricks. This mortar is fire-resistant and it is therefore used with fire-bricks for lining furnaces, fire places, ovens, etc. where the temperature is too high for ordinary mortar.

(ii) Lightweight Mortar:

This mortar is prepared by adding materials such as saw dust, wood powder, etc. to the lime mortar or cement mortar. Other materials which may be added are asbestos fibres, jute fibres, coir, etc. This mortar is used in the sound-proof and heat-proof constructions.

(iii) Packing Mortar:

Slag Portland cement, Puzzolana and sulphate resisting cements are used for aggressive water and packing Portland cement when water pressure is expected. To pack oil wells, special mortars possessing the properties of high homogeneity, water resistance, predetermined setting time, ability to form solid water-proof plugs in cracks and voids of rocks, resistance to subsoil water pressure, etc. have to be formed.

The varieties of packing mortars include cement-sand, cement-loam and cement-sand-loam. The composition of packing mortar is decided by taking into consideration the hydrogeologic conditions, packing methods and type of timbering.

(iv) Sound-Absorbing Mortar:

To reduce the noise level, the sound-absorbing plaster is formed with the help of sound-absorbing mortar. The bulk density of such a mortar varies from 6 (6001200 kg/m3) to 12 kN/m^3 and the binding materials employed in its composition may be Portland cement, lime, gypsum, slag, etc. The aggregates are selected from lightweight porous materials such as pumice, cinders, etc.

(v) X-Ray Shielding Mortar:

This type of mortar is used for providing the plastering coat to walls and ceiling of X-ray cabinets. It is a heavy type of mortar with bulk density over 22 kN/m^3. The aggregates are obtained from heavy rock and suitable admixtures are added to enhance the protective property of such a mortar.

(vii) ***Damp proof mortars –*** are prepared using high grade sulphate-resisting Portland cement or sulphate-resisting Pozzolana cement as binding material and quartz sand or sand from crushed solid rock

(viii) ***Mortars for filling joints*** - Cement-sand and cement paste injection mortars intended for filling grooves inside pre-stressed concrete components should have a grade not less than M-40 grade or more is preferred

1.2.3.4 Learning Activities

a) Practical activity

Perform a permeability test on different types of concrete and mortars provided.

1.2.3.5 Self-assessment test 3

Q1. Which of the following mortars is most suitable for construction work in water-logged areas?

(a) Lime mortar
(b) Gauged mortar
(c) Cement mortar
(d) Mud mortar

Q2. After addition of cement, the gauged mortar should be used within

(a) 30 minutes
(b) 1-2 hours
(c) 8-10 hours
(d) 24 hours

Q3. A gauged mortar is obtained by adding which of the following ingredients to cement?

(a) Sand stone
(b) Sand and surkhi
(c) Sand and lime
(d) Surkhi alone

Q4. Lime mortar is generally made with

(a) quick lime
(b) fat lime
(c) hydraulic lime

(d) white lime

Q5. One of the main demerits in using the lime mortar is that it

(a) is not durable
(b) does not set quickly
(c) swells
(d) is plastic

1.2.3.6 Tools, Equipment, Supplies and Materials

a) Tools and equipment

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

b) Materials and supplies

- Computer software
- Construction materials
- Computers
- Stationery

c) Manufacturer's catalogues

- Personal protective equipment (PPEs)
- Safety boots
- Goggles
- Gas masks
- Helmets
- Gloves
- Dust coats
- First aid kit
- Ear muffs
- Dust masks
- Overalls

1.2.3.7 References

Akroyd, T. N. W. (2016). *Concrete: properties and manufacture*. Elsevier.

Dupray, S., & Roberts, J. (2009). Review of the use of concrete in the manufacture of concrete armour units. *Proceedings of Coasts, Marine Structures and Breakwaters*, 260-271.

Eliche-Quesada, D., Martínez-García, C., Martínez-Cartas, M. L., Cotes-Palomino, M. T., Pérez-Villarejo, L., Cruz-Pérez, N., & Corpas-Iglesias, F. A. (2011). The use of different forms of waste in the manufacture of ceramic bricks. *Applied Clay Science*, *52*(3), 270-276.

Fernandes, F. M., Lourenço, P. B., & Castro, F. (2010). Ancient clay bricks: manufacture and properties. In *Materials, technologies and practice in historic heritage structures* (pp. 29-48). Springer, Dordrecht.

Srivastava, A., & Singh, S. K. (2020). Utilization of alternative sand for preparation of sustainable mortar: A review. *Journal of Cleaner Production*, *253*, 119706.

Taha, Y., Benzaazoua, M., Hakkou, R., & Mansori, M. (2016). Natural clay substitution by calamine processing wastes to manufacture fired bricks. *Journal of Cleaner Production*, *135*, 847-858.

https://civilblog.org/2015/04/08/what-are-the-quality-requirements-of-common-clay-building-bricks/

https://theconstructor.org/building/manufacturing-of-bricks-methods-and-process/11972/

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.brainkart.com%2Farticle%2FManufacturing-Of-Bricks_3590%2F&psig=AOvVaw0RZxWp5unfjMn4sLgJC47F&ust=1626373112556000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDr6YeW4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.brainkart.com%2Farticle%2FManufacturing-Of-Bricks_3590%2F&psig=AOvVaw0RZxWp5unfjMn4sLgJC47F&ust=1626373112556000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDr6YeW4_ECFQAAAAAdAAAAABAD

https://i1.wp.com/theconstructor.org/wp-content/uploads/2016/06/tempering-of-clay-for-manufacturing-of-bricks.jpg?resize=476%2C370&ssl=1

https://www.engineeringenotes.com/engineering-materials-2/bricks/how-to-manufacture-bricks-brick-manufacturing-process-with-top-4-steps/46399

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.brainkart.com%2Farticle%2FBricks-Moulding_3592%2F&psig=AOvVaw3oMawa-x9fy_vzRA9ZWEay&ust=1626373758653000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDxocKY4_ECFQAAAAAdAAAAABAD

http://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0cdl--00-0----0-10-0---0---0direct-10---4-------0-1l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-00&cl=CL2.19&d=HASH019ecdd8cfb449300837c8a2.9&gt=1

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.civilengineerspk.com

%2Fdrying-of-bricks%2F&psig=AOvVaw0A3a9xMcUwLjtA8Ejg5Q2D&ust=1626373959163000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCKia5pyZ4_ECFQAAAAAdAAAAABAD

https://www.engineeringenotes.com/engineering-materials-2/bricks/how-to-manufacture-bricks-brick-manufacturing-process-with-top-4-steps/46399

https://www.civilengineerspk.com/burning-of-bricks/

https://i2.wp.com/civilengineerspk.com/wp-content/uploads/2016/12/Burning-of-Bricks2.jpg

https://www.engineeringenotes.com/engineering-materials-2/bricks/how-to-manufacture-bricks-brick-manufacturing-process-with-top-4-steps/46399

https://www.thesprucecrafts.com/what-kind-of-kiln-is-it-2746127

https://www.allrefractory.com/solution/refractories-recommendation-for-shuttle-kiln- and-tunnel-kiln-linings/

https://www.researchgate.net/figure/Schematic-representation-of-the-tunnel-kiln_fig1_288044522

https://www.google.com/url?sa=i&url=https%3A%2F%2Fcivileblog.com%2Fmixing-concrete%2F&psig=AOvVaw0__0C7Tx9tzy3Ot1N--mEP&ust=1626374124219000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNjgiemZ4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.toolstoday.co.uk%2Fbelle-premier-100xt-electric-start-mobile-cement-mixer&psig=AOvVaw37dVQXpssViZIBHUgfeqO7&ust=1626374574140000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCJDMyMWb4_ECFQAAAAAdAAAAABAH

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Ffully-automatic-batching-plant-7869762897.html&psig=AOvVaw2fdXVPsU5jbNZki-ZpX9zH&ust=1626374930890000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCJDlm-qc4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.nilkanthmachinetools.com%2F&psig=AOvVaw2b67KzVmsGSyA7G2nIWGPm&ust=1626374978311000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLDWgIad4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.nilkanthmachinetools.com%2F&psig=AOvVaw2b67KzVmsGSyA7G2nIWGPm&ust=1626374978311000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLDWgIad4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.boxley.com%2Fconcrete.html&psig=AOvVaw2wQ7rGDUW_4HdOL6Gwjo09&ust=1626374710870000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNiyspKc4_ECFQAAAAAdAAAAABAI

https://gosmartbricks.com/everything-about-mortar-in-construction/

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.brainkart.com%2Farticle%2FLime-Mortar_3602%2F&psig=AOvVaw3Wu19hV4A6Jymz19x5sKmP&ust=1626375228257000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCKjO2_2d4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.brainkart.com%2Farticle%2FLime-Mortar_3602%2F&psig=AOvVaw3Wu19hV4A6Jymz19x5sKmP&ust=1626375228257000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLjPtauf4_ECFQAAAAAdAAAAABAD

https://www.civilengineeringx.com/mortars/lime-mortar/

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.omnia.ie%2Findex.php%3Fnavigation_function%3D3%26europeana_query%3DMixers&psig=AOvVaw3dzdTKXUlXQmkyKnh_ZQG_&ust=1626375040618000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCKjcl6Od4_ECFQAAAAAdAAAAABAH

1.2.3.8 Responses to self-assessment test 3

Q1. C
Q2. B
Q3. C
Q4.C
Q5. B

1.2.4 Learning Outcome 4: SELECT QUALITY CONSTRUCTION MATERIALS

1.2.3.1 Introduction to learning outcome

This learning outcome specifies the content of competencies required to Select quality construction materials. It includes; Properties of quality construction

materials, Construction materials Cost and quality relationship and Selection of Construction materials.

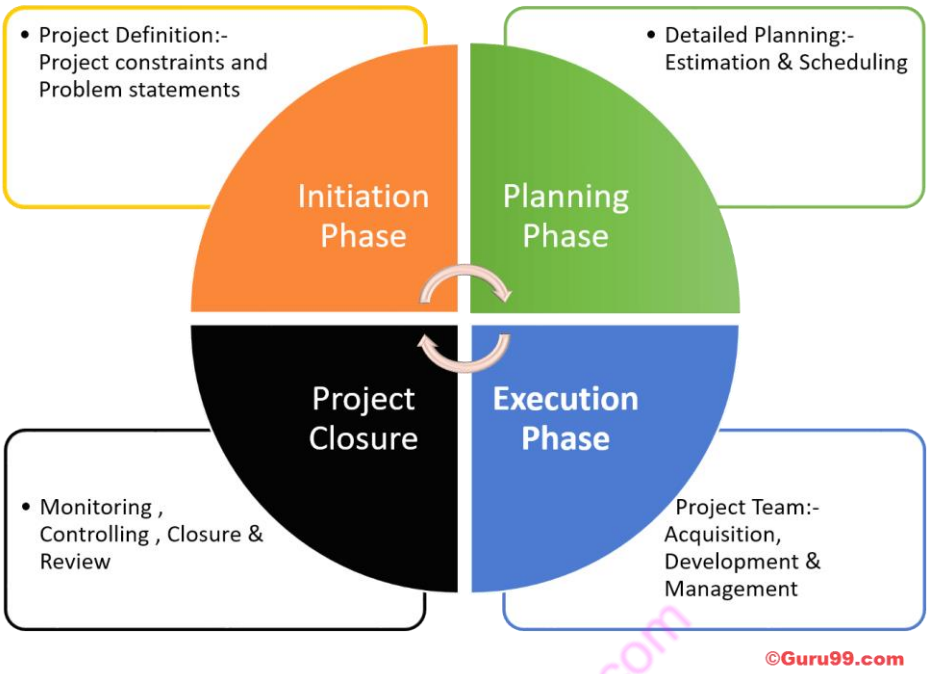
1.2.4.2 Performance standards

a) Cost implications of construction materials are evaluated and analyzed
b) Quality construction materials are selected based on their costs and project requirements

1.2.4.3 Information sheet

a) Definition of terms

- **Analysis-**
  detailed examination of the elements or structure of something
- **Evaluation-**
  the making of a judgment about the amount, number, or value of something; assessment
- **Maintenance costs-**
  costs incurred on a regular basis to keep an asset working in its optimal condition.
- **Durability-**
  the ability of a physical product to remain functional, without requiring excessive maintenance or repair, when faced with the challenges of normal operation over its design lifetime
- **Project life cycle** –
  refers to the sequence of phases that a project goes through from its initiation to its closure.



https://www.guru99.com/initiation-phase-project-management-life-cycle.html

Fig. 49- Four Phases Of Project Management Life Cycle

- **Costs-** the expenses incurred from the start to the end of a project or to obtain something
  - **Fixed costs** –
    These are costs that do not vary with the level of output in the short term.
  - **Variable costs –**
    Varies in direct proportion with the level of output. Varying directly means that the total variable cost will be totally dependent on the level of output.
  - **Semi-variable cost** –
    Expenses which includes a mixture of fixed and variable components. These costs vary (change) with output, but not in direct proportion
  - **Total costs** –
    The sum of fixed costs, semi-variable costs and variable costs for any particular level of output.
  - **Direct costs** –
    Any cost which is directly related to the output level of a particular product or department.
  - **Indirect costs** –
    Any cost, which cannot be linked with the output of any particular product or department. These costs are also known as **indirect overheads** or **administrative costs**.

NB; In construction, it is essential to pre-consider all the costs to be incurred from the start to the end of the project. Expenses may range from labor to cost of materials to clearance and certification costs.
Costs incurred in such cases may include;

- *initial cost of purchase*
- *life cycle costs of materials* :
  - Maintenance
  - Replacement
  - Demolition
  - Durability

b) Properties of quality construction materials

- **Durability** –
  High-quality materials is sure to have a long life expectancy. Low-quality materials are prone to cracks and breaks. Quality materials also ensure a lower need for maintenance and that your property always looks its best.
- **Cost Efficiency –**
  Both short and long term, quality materials in construction ensure that you save on costs where choosing quality materials from the beginning can avoid bigger problems at a later time.
- **Safety –**
  Quality materials have higher endurance and resistance to both time and weather conditions, which provides you with a higher assurance of safety.
- **Sustainability –**
  The right materials need to be taken into account in order to provide a sustainable future prompting materials to become more environmentally friendly.

c) Comparison of various building materials

Material	Ease of installation	Initial cost	Maintenance cost	Recycling & re-using	Capability& durability
Concrete	Requires specialized skills and equipment	Medium-High costs depending on process used	Low-medium but may increase if coated	May be crushed and re-used as aggregate in new concrete or for paving	Excellent strength and remains durable even when wet
Timber	Relatively light to handle	Low-medium depending on certification and clearance	Very high 4 often recoated timber Low-median for interior painted	Some salvaged material can be recycled or reused	Durability depends on species, type & level of treatment and environmental conditions

			timber		
Steel	Light and easy to handle	Medium-high costs depending on size of steel used.	Little maintenance is required in dry & protected areas	Has highest recycling rates Steel cladding in can be re-used	High strength: weight ratio Durability can be improved with correct protection
Cement-based plaster	Requires moderate to special skills	Low costs	Moderate costs	Can be crushed and reused for paving	Very strong and durable
Stone	Natural stone is labor intensive to install Requires special skills	Relatively high	Low maintenance costs	May be re-used if carefully removed Can be crushed and recycled as aggregate or decorative chips	Very durable
Roof tiles	Can be easily handled by average site labor	Upfront costs are relatively high	Low costs proper care has to be taken as th tiles can be easily damaged during repairs	Can be re-used if carefully removed May be crushed with concrete roof tiles for use in under footpaths	Are not a structural element Very durable with spans of up to 50 years
Plaster boards	Continued contact with gypsum may result to skin irritation	Low-medium depending on specification	Low costs of maintenance	Can be reused if undamaged Can be recycled	Can be used as a structural component Moderately durable

d) Key Factors Affecting Strength of Concrete are:

Strength of concrete or in other words, the *compressive strength of the concrete*, dominant factor considered in the structural design in addition to the strength of the reinforcements.

The factors are as follows:

1. ***Quality of the materials such as cement, coarse aggregate, fine aggregate, and water***
2. ***Water Cement ratio***

3. ***Air entrainment***
4. ***Aggregate proposition (Coarse: Fine)***
5. ***The ratio of Aggregate to Cement***
6. ***Curing period***
7. ***Use of Admixtures***
8. ***Compaction of Concrete***
9. ***Time after concreting(Age of concrete)***
10. ***Temperature***
11. ***Relative humidity***

Each factors affecting strength of concrete are discussed as follows:

1. Quality of Raw Materials

Mainly there are four materials used to make the concrete.

- Cement
- Coarse aggregate
- fine aggregate
- and water

The effect of each of the materials can be discussed separately.

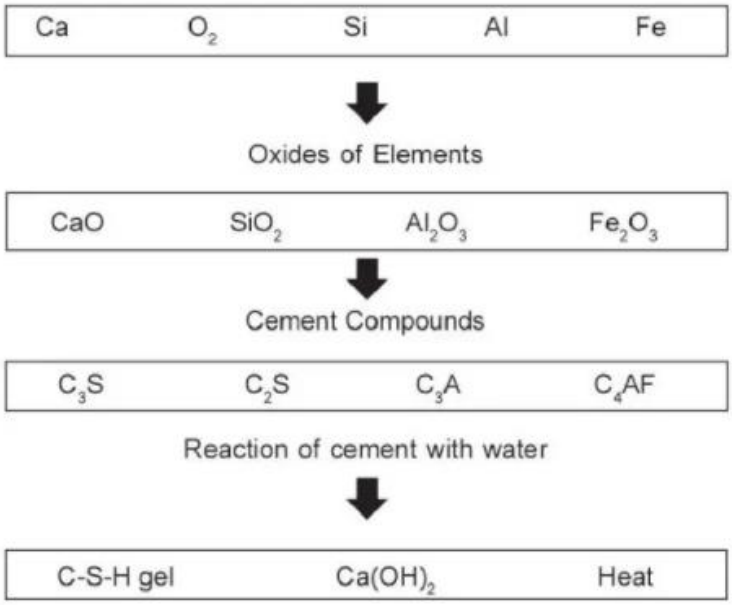
https://www.structuralguide.com/factors-affecting-strength-of-concrete/

Fig.50- Raw Materials for Concrete

- ***Cement:***

cement is the material that creates the bond between aggregate after reaction with the addition of the water. Provided the cement conforms with the appropriate standard and it has been stored correctly (i.e. in dry conditions), it should be suitable for use in concrete.

The hydration process can be represented by the following equation.



https://www.structuralguide.com/factors-affecting-strength-of-concrete/
Fig. 51- Cement Hydration process Equation

The use of quality cement improves the bond and strength. The strength of the cement depends on the date of the manufacture.

https://www.structuralguide.com/factors-affecting-strength-of-concrete/
Fig. 52- Fine Cement Powder

Similarly, there are several aspects that should be looking into when considering the quality of the cement.

- Date of packing.
- Color.
- Rubbing.
- Hand Insertion.
- Float Test.
- Smell Test.

- Presence of lumps.
- Shape Test.
- Strength Test.

In addition, there are other *cement tests* to be carried out to find the quality of the cement.

- Fineness.
- Compressive strength.
- Heat of hydration.
- Initial and final setting times.
- Soundness.
- Normal Consistency.

In general, cement is considered one of the highly influential factors affecting strength of concrete.

- ***Aggregates:***

Aggregate is the material bond with the cement paste after reacting with water. Therefore, the quality of aggregates, its size, shape, texture, strength etc. determines the strength of concrete. The presence of salts (chlorides and sulphates), silt and clay also reduce the strength of concrete.

Generally, 80% of the volume concrete is filled by aggregates.

There are two types of aggregates namely coarse aggregate and fine aggregate.

The following factors are considered to maintain the quality of the aggregates:

- Particle size distribution/gradation.
- Shape and texture.
- Moisture content.
- Specific gravity.
- Reactivity.
- Soundness.
- Bulk weight.

The above mention characteristic influences workability, finishability, bleeding, and segregation of fresh concrete effects the strength, shrinkage, density, and durability of hardened concrete.

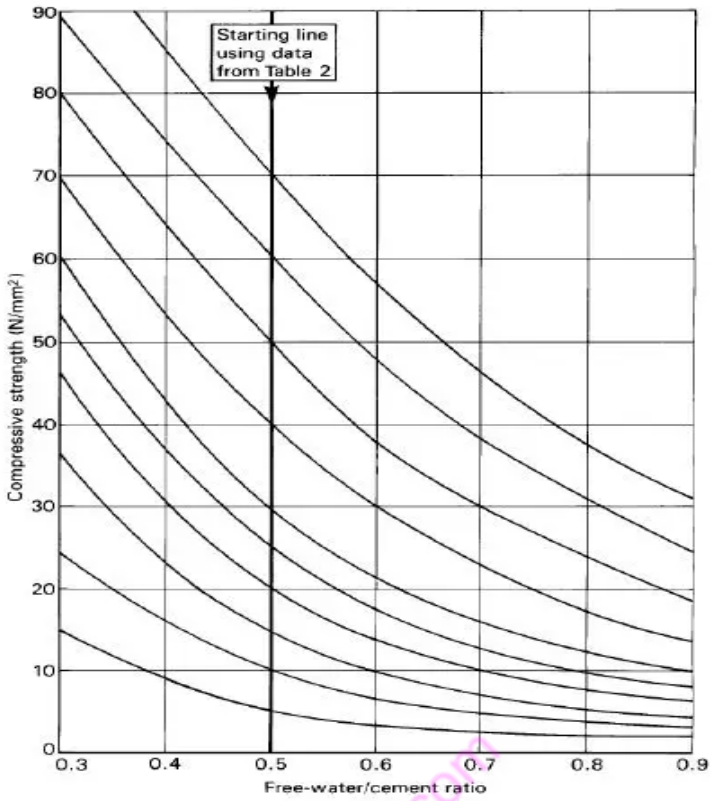
- ***Water:***

Frequently the quality of the water is covered by a clause stating "..the water should be fit for drinking..". This criterion though is not absolute and reference should be made to respective codes for testing of water construction purpose.

2. Water /Cement Ratio

The water-cement ratio is one of the most important factors affecting strength of concrete. Depending on the water-cement ratio, the compressive strength is defined in the mix designs.

When we required a certain grade of concrete, firstly we select an appropriate water-cement ratio to proceed with the mix design.



https://www.structuralguide.com/factors-affecting-strength-of-concrete/
Fig. 53- Water/Cement Ratio

As indicated in the above figure, the increase of the water/cement ratio reduces the compressive strength of the concrete. Water/Cement ratio can be increased by increasing the water content or by reducing the cement content.
At present, the use of *admixtures* that reduce the content of water to be used to retain the expected workability has made a considerable impact on this ratio.
The use of new admixtures has brought more advantages to the industry and also the risk. All those will be discussed in the latter part of this article.

3. Air Entrainment

In general, air entrainment in the concrete reduces its strength.
An increase in the volume of air voids by 1% reduces the strength by 5%.
However, internally entrained air voids improve the resistance of concrete to damage from cycles of freezing and thawing.
Further, it improves the workability of the concrete.
The following figure also indicates the variation of the compressive strength of concrete with the water-cement ration based on the entrainment of air.

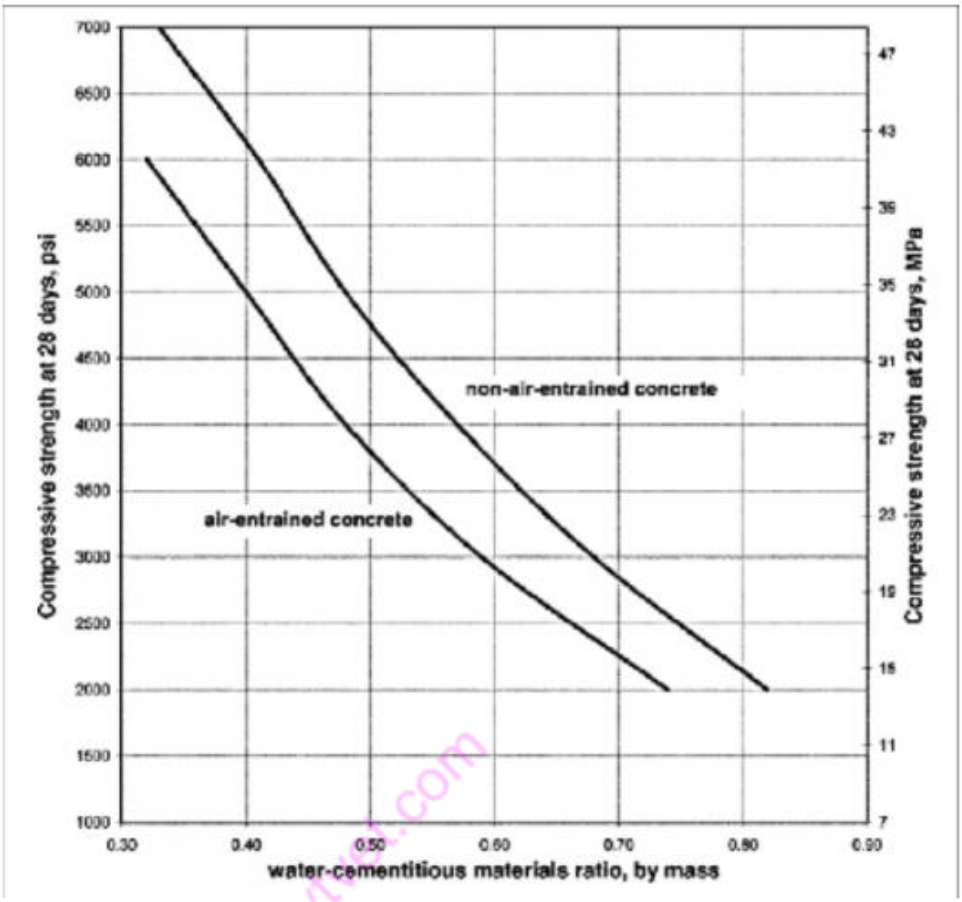


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Fig. 54- Air Entrainment in the Concrete

4. Aggregate Proportion (Coarse/fine aggregate ratio)

Following points should be noted for coarse/fine aggregate ratio:

- If the proportion of fines is increased in relation to the coarse aggregate, the overall aggregate surface area will increase.
- If the surface area of the aggregate has increased, the water demand will also increase.
- Assuming the water demand has increased, the water cement ratio will increase.
- Since the water cement ratio has increased, the compressive strength will decrease.

Aggregate proportions are greatly affecting the strength.
Usually, we have a fine and coarse aggregate. Sand and the quarry dust is used as fine aggregate.
All of these aggregates, their properties shall be checked according to the standards and the gradation of the materials shall also be within the acceptable range.
Whenever there is a change in the source of the material, verification shall be done.
Since the particle size greatly affects the compressive strength, they shall be checked regularly.

In a concrete, mix proportions of cement, water, coarse and fine aggregates decides the strength of the concrete. Different strengths can be achieved for different mix proportions.
When the mix designs are done, mix proportion of the aggregates are considered as one of the most important factors.

5. Ratio of Aggregate to Cement

Following points must be noted for aggregate cement ratio:

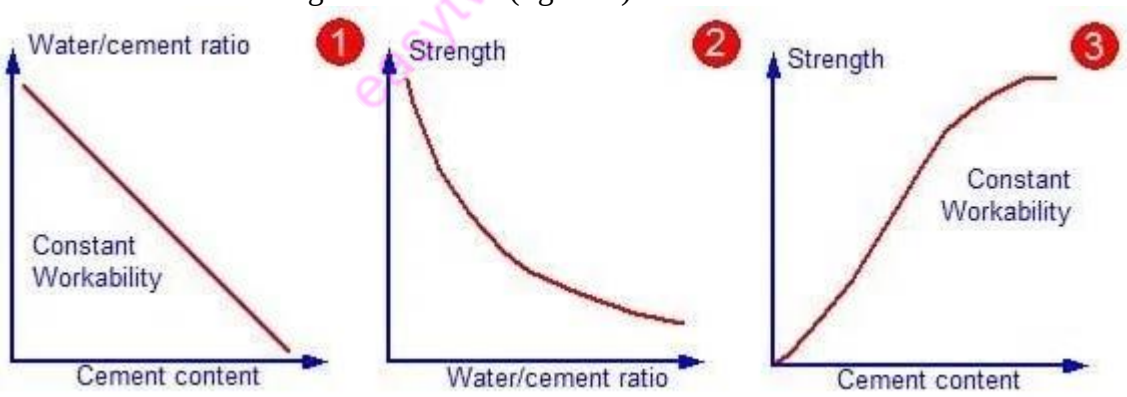
- If the volume remains the same and the proportion of cement in relation to that of sand is increased the surface area of the solid will increase.
- If the surface area of the solids has increased, the water demand will stay the same for the constant workability.
- Assuming an increase in cement content for no increase in water demand, the water cement ratio will decrease.
- If the water cement ratio reduces, the strength of the concrete will increase.

The influence of cement content on workability and strength is an important one to remember and can be summarized as follows:

(i) For a given workability an increase in the proportion of cement in a mix has little effect on the water demand and results in a reduction in the water/cement ratio.(fig.62-1)

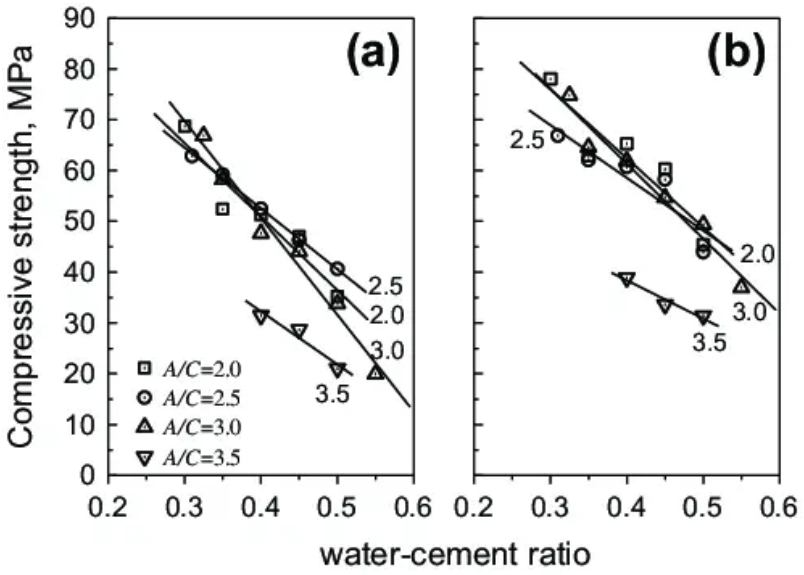
(ii) The reduction in water/cement ratio leads to an increase in strength of concrete.(fig.62-2)

(iii) Therefore, for a given workability an increase in the cement content results in an increase in strength of concrete.(fig.62-3)



https://theconstructor.org/concrete/factors-affecting-strength-of-concrete/6220/
fig. 55- Aggregate/ cement ratio.

The majority of the volume of concrete is represented by the aggregates; fine aggregates and coarse aggregates.
Cement after reacting with water create the bond with the aggregates to create the concrete.
Cement content and aggregate volume ratio is related to the strength of the as shown in the following figure extracted from a technical paper.



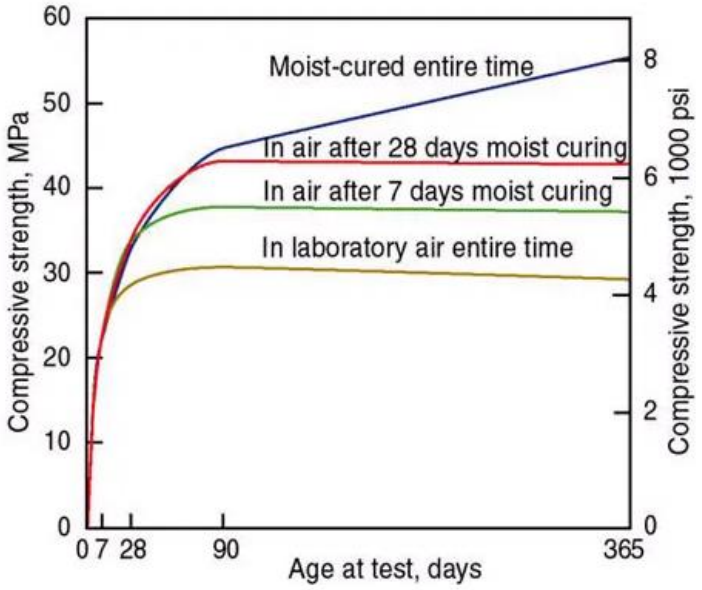
https://www.structuralguide.com/factors-affecting-strength-of-concrete/

Fig. 56- Aggregate/ cement ratio.

6. Curing Period

It should be clear from what has been said above that the detrimental effects of storage of concrete in a dry environment can be reduced if the concrete is adequately cured to prevent excessive moisture loss.

The period of curing of concrete is directly affecting the strength development of the concrete. The article published in this website *Factors affecting Curing Time of Concrete* provides detailed information on the curing period of concrete.



https://www.structuralguide.com/factors-affecting-strength-of-concrete/

Fig. 57- Curing period on strength development

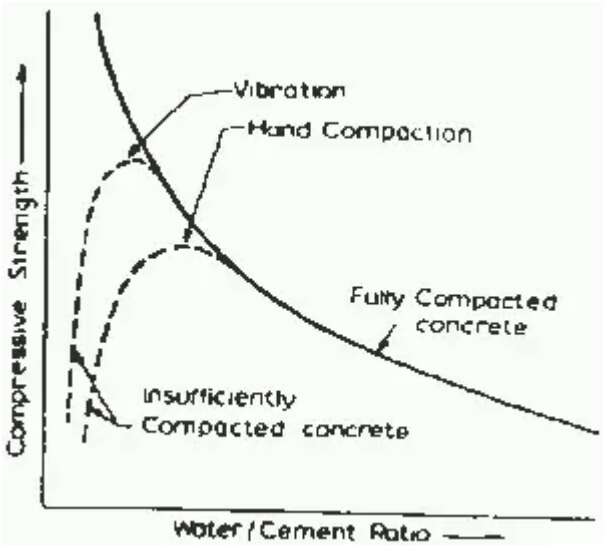
As indicated in the figure 64 above, and due to the importance of curing of concrete to gain its strength, curing shall not be avoided.
In addition to the strength gain, the curing of concrete improves its durability, cracking when it hardening, etc.

7. Use of Admixtures

At present, almost all the time, admixtures are used for all the concreting work. It adds more advantages.
With the current developments in this industry, there are admixtures that can provide multiple functions such as retarding and water reducing actions.
As we know, superplasticizers are widely used as admixture due to its advantages.
These admixtures are categorized under chemical admixtures.
Superplasticizers reduce the water requirement by 15 to 20% without affecting the workability leading to high strength and dense concrete. This strength increase will be for the same cement content with the reduction of the amount of water.
Further, we can reduce the cement content by adding a superplasticizer to keep the required strength. By that, we can save some money.
However, the dosage of the admixtures shall be as specified by the manufacturer.
Overdosage could reduce compressive strength also.

8. Compaction of Concrete

Any entrapped air resulting from inadequate compaction of the plastic concrete will lead to a reduction in strength. If there was 10% trapped air in the concrete, the strength will fall down in the range of 30 to 40%.
It is quite clear that compaction directly affects strength.
Poorly compacted concrete has less strength as shown in the following figure.

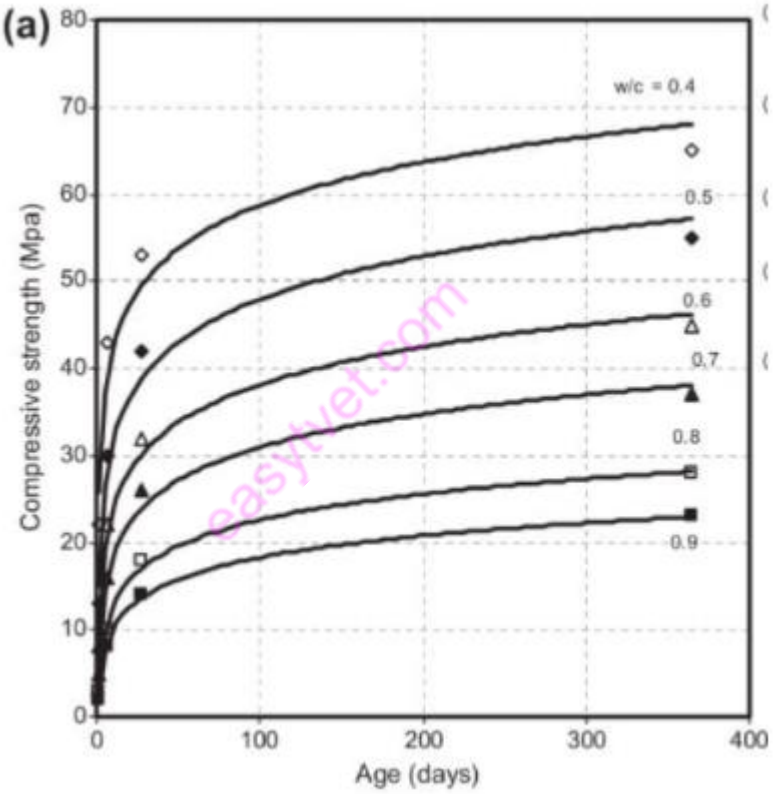


https://www.structuralguide.com/factors-affecting-strength-of-concrete/
Fig. 58- Compaction of Concrete

Poorly compacted concrete has more voids and as a result, it reduces the bond between the aggregates.
Therefore, it is very important to compact concrete adequately.

9. Time After Concreting (Age of Concrete)

The degree of hydration is synonymous with the age of concrete provided the concrete has not been allowed to dry out or the temperature is too low. In theory, provided the concrete is not allowed to dry out, then it will always be increasing albeit at an ever-reducing rate. For convenience and for most practical applications, it is generally accepted that the majority of the strength has been achieved by 28 days.
The age of the concrete is an indication of the strength development of concrete.
With time concrete strength increases but it does not increase proportionately.



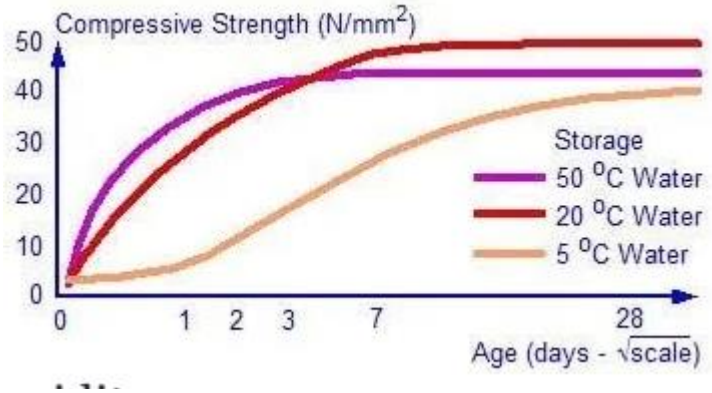
https://www.structuralguide.com/factors-affecting-strength-of-concrete/
Fig. 59- Age of Concrete

Time is the main factor that reflects the strength of the concrete. When the concrete getting older, its strength increases. However, beyond a certain period, the increase of the strength is minimal.

10. Temperature

The rate of hydration reaction is temperature dependent. If the temperature increases the reaction also increases. This means that the concrete kept at higher temperature will gain strength more quickly than a similar concrete kept at a lower temperature. However, the final strength of the concrete kept at the higher temperature will be lower. This is because

the physical form of the hardened cement paste is less well-structured and more porous when hydration proceeds at faster rate. This is an important point to remember because temperature has a similar but more pronounced detrimental effect on permeability of the concrete.

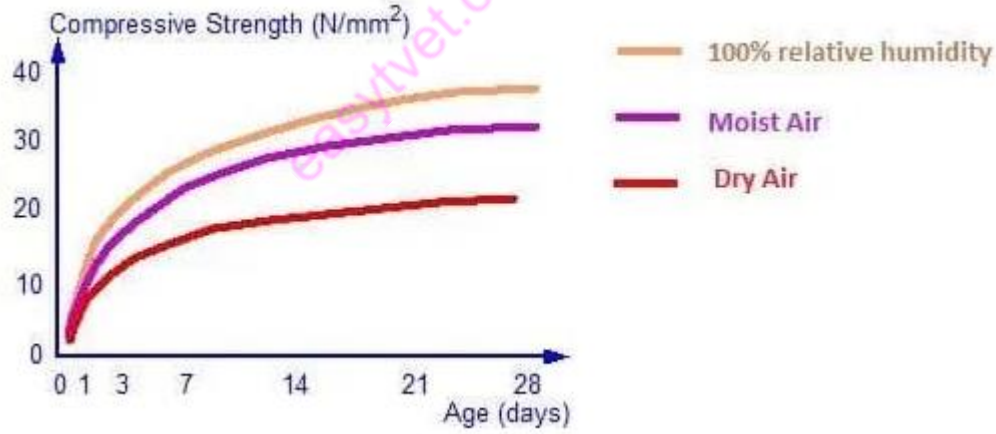


https://www.structuralguide.com/factors-affecting-strength-of-concrete/

Fig. 60- Temperature

11. Relative Humidity

If the concrete is allowed to dry out, the hydration reaction will stop. The hydration reaction cannot proceed without moisture. The three curves shows the strength development of similar concretes exposed to different conditions.



https://www.structuralguide.com/factors-affecting-strength-of-concrete/

Fig. 61- Relative humidity

d) Reinforced Concrete construction quality depends on the following Factors:

- Integrity, cleanliness, size grading of the aggregate;
- Size & cleanliness of sand;
- Cleanliness of water;
- Quality of cement;
- Mix design ratio of stone: sand: cement and, the water: cement ratio.
- Method and duration of mixing all ingredients.
- Appropriate mode of carrying/pumping pouring and setting wet concrete.
- Material, surface quality, dimensional tolerance, and adequate support of shuttering.

- Curing throughout the period of strength gain, usually 28 days.

e) Structural Steel construction quality depends on the following factors:

- The strength and consistency of strength of structural steel; I-sections, L-angles, C-sections, which should be fabricated from hot rolled billets.
- Efficiency and correctness of Joint design, often by welding, or bolting.
- Welded joint strength depends on the welding material, type, and quality, which must be assured with consistent non-destructive testing.
- Bolted joint strength depends on the configuration, bolt material, and amount of tightening, which can only be ensured by using calibrated torque wrenches.
- Sequence of construction, which done improperly may induce residual stresses.
- Buildings constructed of structural steel are more flexible, and therefore better for earthquake design.

NB; - the integration of steel frames to brittle elements such as infill brick walls and glass facades require special details.

f) Factors in which selection of construction materials depends upon are:

There is a wide range of building materials available in the market and it can be difficult to decide the best options for your various needs as the selection of construction material requires to take note of various factors which are:

- Strength
- Life of the material
- Budget/Cost of material
- Handling and Storage
- Local availability
- Climate
- Skill required and its availability
- Sustainability
- Nature of project
- Aesthetic appeal
- Specifications
- Warranty or guarantee
- After sales support and service
- Maintenance

01. Strength

Strength is an essential parameter for quality control in the construction and most important selection criteria for building material. It shows the ability of a material to withstand the failure under the action of stresses caused by loads such as compression, tension, bending and/or impact etc. that can be caused either due to the forces of nature or can be man-made.

02. Life of Material

House is what you make one time in a lifetime. Hence for the long life of the building, all materials should have long and maintenance free life. The durability of the house depends on the materials used so don't cut corners or else be ready to pay hefty maintenance costs.

03. Cost of Material

Cost of material is one important factor while choosing the material for construction as ultimately it will lock your choice willingly.

04. Handling and Storage

While selecting the building materials, it's necessary to take into account their handling and storage because it affects the construction time, requirement of labour and equipment for handling, and of course the cost.

05. Local Availability

Availability of building materials also affects the cost and the time of construction because certain materials are available at a particular place and are difficult to transport. In that case, not only the transportation costs will be very high but it will also delay the work. On the other hand, if the material is locally available it decreases the transportation cost. It's also a time saver and construction work can also be done smoothly.

06. Climate

Another important aspect of the choice of materials is the climate. Factors like the average range of temperature throughout the year, rain or snowfall, seasons, amount of sunlight, required ventilation and wind are areas of concern. Hence chosen material for construction should complement the climate. When climate comes in the picture automatically the properties of materials also come in the picture.
Therefore, make sure that the materials you choose are according to the climate you are building house in.

07. Skills Required and its Availability

While selecting the material it is important to know the extent of skill required to use such materials. It may increase the cost of the construction because you have to appoint/hire a skilled person (labour) to use that material and if the skilled person or labour is not available particularly in remote areas then it will delay the work.

08. Sustainability

With the development of the construction industry, the demand for building materials is increasing, and also responsible for the rise in carbon footprint, i.e. use of cement increases the carbon emission. Hence eco-friendly and sustainable building materials like GGBS- ground granulated blast furnace slag, fly ash, meta kaolin, silica fume, rice husk ash etc. rather than the use of cement.

09. Nature of Project

Choice of material is a great deal in construction. The choice of material should be done cautiously as it directly affects the user. One significant area of concern which governs the choice of material is the nature of the project. Nature of project means residential, commercial, gathering space etc. The material used defines the built space. It also leads to other key factors like investment budget.

10. Aesthetic Appeal

Everyone has different tastes and requirements and therefore, if one person considers something attractive, it may not appeal to the next. Only you know what kind of home/construction/building you will like to live in. As an example, the type of flooring material you select can change the look of the home or building. Hence, you have to select a flooring material which will not only suit your tastes but also fits into your budget such as e vitrified tiles, ceramic tiles, granite, marble, kota stone, wood etc.

11. Specifications

Based on your requirements like strength, aesthetic look etc. you should define the specifications and quality of materials that would go into the house. Assume you want to purchase cement for construction then it's essential to know what type of cement you want to purchase whether OPC or PPC, cement grade etc.

12. Warranty or Guarantee

While buying any material also check the product literature, technical specifications, terms and conditions of the warranty, guarantee etc. that is usually mentioned on the packaging or described on the website of the dealer or manufacturers because sometimes what the salesperson presents to you or otherwise what is understood by you can be an eyewash. So, take time when you go through the product literature so that you have the right products and no regrets.

13. After Sales Support and Service

While purchasing the materials keep in mind that support and services are essential after sales. Hence, you have to check that seller provides support and service like spares, normal repairing or annual maintenance etc.

14. Maintenance

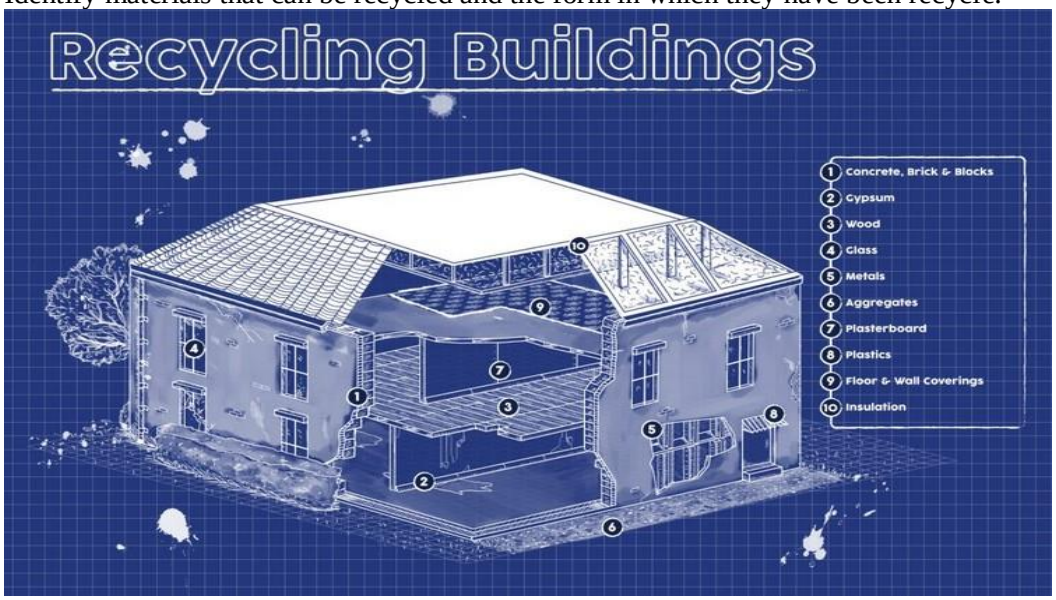
Maintenance is also an important selection criterion for construction material because the good materials are those which are easy and economical to maintain. Maintenance will help to keep the look of building for a long time period and will increase the life of the building.

1.2.4.4 LEARNING ACTIVITY

a) Practical Activity

i. Identify the alternative that can be used in place of the materials used in the diagram.

ii. Identify materials that can be recycled and the form in which they have been recycle.



https://www.google.com/url?sa=i&url=http%3A%2F%2Frubberbond.co.uk%2Fblog%2Frecycling-buildings-10-building-materials-that-can-be-reused-after-demolition%2F&psig=AOvVaw0dDs5rzFE-cUztxJfpYvro&ust=1626376034190000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCJD28feg4_ECFQAAAAAdAAAAABAD

Figure 62;Recycling of materials

1.2.4.5 Self-assessment test 4

Q1. Which of the following is not a sustainable planning practice?
A).Reuse of existing structure and materials
B).Heritage Impact Assessment
C).Energy Audit

Q2. Which of the following is a reusable building material from demolished buildings when constructing new buildings?
A).Bricks
B).Paint
C).Carpet

Q3.Which land use is considered incompatible with residential neighbourhoods?
A).Commercial use
B).Industrial use
C).Residential use

Q4. Using recycled-content building materials can _____ waste as well as pollution and energy associated with the mining, harvesting of raw materials.
A).increase
B).create
C).reduce

Q5. Which of the following statement is true?
A).Using non-renewable materials can reduce the environmental impacts.

B).Using new building materials can reduce waste disposal.
C).Using recycled-content materials can enable the reuse of waste and thus reduce waste disposal.

1.2.4.6 Tools, Equipment, Supplies and Materials

a) **Tools and equipment:**

- computer
- Hand tools
- Machine tools

b) **Materials and supplies:**

- Computer software
- Construction materials
- Computers
- Stationery
- Manufacturer's catalogues

c) **Personal protective equipment (PPEs):**

- Safety boots
- Goggles
- Gas masks
- Helmets
- Gloves
- Dust coats
- First aid kit
- Ear muffs
- Dust masks
- Overalls

1.2.4.7 References

Abdelrahman M., Saboori A. (2012) Waste Materials in Construction, Utilization of. In: Meyers R.A. (eds) Encyclopedia of Sustainability Science and Technology. Springer, New York, NY. https://doi.org/10.1007/978-1-4419-0851-3_117

Calkins M (2009) Materials for sustainable sites: a complete guide to the evaluation, selection and use of sustainable construction materials. Wiley, Hoboken

Kamaruddin, M. A., Abdullah, M. M. A., Zawawi, M. H., & Zainol, M. R. R. A. (2017, November). Potential use of plastic waste as construction materials: recent progress and future prospect. In *IOP Conference Series: Materials Science and Engineering* (Vol. 267, No. 1, p. 012011). Iop Publishing.

https://www.guru99.com/initiation-phase-project-management-life-cycle.html

https://www.structuralguide.com/factors-affecting-strength-of-concrete/

https://theconstructor.org/concrete/factors-affecting-strength-of-concrete/6220/

https://www.google.com/url?sa=i&url=http%3A%2F%2Frubberbond.co.uk%2Fblog%2Frecycling-buildings-10-building-materials-that-can-be-reused-after-demolition%2F&psig=AOvVaw0dDs5rzFE-cUztxJfpYvro&ust=1626376034190000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCJD28feg4_ECFQAAAAAdAAAAABAD

1.2.4.8 Responses to self- assessment test 4

Q1. C

Q2. A

Q3. B

Q4. C

Q5. C

1.2.5 Learning outcome 5; USE CONSTRUCTION MATERIALS APPROPRIATELY

1.2.6.1 Introduction to learning outcome

This learning outcome specifies the content of competencies required to Use construction materials appropriately. It includes; Construction methods and processes and Appropriate use of construction materials.

1.2.6.2 Performance standards

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

5.2 Construction materials are used based on construction process.

1.2.6.3 Information sheet

a) Definition of terms

- **Equipment-**
  The requirements needed for a given purpose or to complete a given task.
- **Construction methods-**
  The techniques and tactics a contractor employs to complete construction of a permanent project or structure.
- **Construction process-**
  A combination of all the physical processes of building, landscaping or refurbishing plus all the associated activities, such as demolition, site clearance and administration.
  Stages of construction involve;
  - **Creating a concept and design**-
    create a concept, followed by a design and blueprints which is done with the help of an architect to ensure everything is up-to-code and that the design will be structurally-sound and stable.
  - **Obtaining building permits –**
    you will need to obtain the right building and construction permits
  - **Clearing and excavating the land –**
    construction project will commence by clearing and excavating the land upon which to build. It includes removing any trees, boulders or other obstacles that are in the way of your building, and leveling or grading the ground
  - **Pouring the foundation** –
    When the space is cleared and excavated, the foundation can be poured. Depending on the size of your building and the stability of the land, preparing the subsurface may need to be done prior to the foundation being poured.
  - **Completing the framing** –
    Once the foundation has been poured and cured, framing begins on your building. This may include installing wood frames or steel beams.
  - **Doing rough electrical and plumbing** –
    a specialty contractor completes rough electrical and plumbing work which involves installing the pipes and wires where they need to go.
  - **Installing the roof** –
    roofers come in to complete the roof on the building which needs to be done before any further work inside of the building can take place, as rain and outdoor elements can damage the work that is taking place in the next few steps
  - **Taking care of heating and cooling needs-**

Vents, ductwork and the heating and cooling unit are all installed.

- **Completing the interior –**
  This includes adding insulation, putting up drywall and adding ceilings. An electrician often comes out during this stage and finishes up adding outlets and lighting fixtures.
- **Installing fixtures** –
  This includes things like toilets, cabinets, windows, doors and elevators
- **Finishing up** –
  The last stage of construction involves putting the finishing touches on the building. This involves installing flooring, painting the walls, putting countertops in or adding faucets in the bathrooms.

b) EARTH MOVING EQUIPMENT

- **Excavators**
  - ***Crawlers***- crawlers run on large two endless tracks, crawlers are often used in mining and heavy-duty construction jobs. Also known as compact excavators, these excavators use hydraulic power mechanisms to lift heavy debris and soil.
  - ***Dragline***- commonly used in large scale civil engineering projects like canal dreading, underwater options, road excavations and pile driving
  - ***Suction/vacuum excavators***- underground applications, delicate digging projects and debris clean up
  - ***Skid steel excavators***- They are often used for digging pools, site cleaning, residential work, and debris removal, where space is more limited and objects are spread out apart.
  - ***Long reach excavators***- best used for heavy duty digging and demolition projects like structural crumpling and breaking down walls and applications that are over a body of water.
- **Graders -** a narrow multipurpose construction machine used to flatten a surface during grading projects**.**
- **Loaders**
  - ***Back hoe***- highly productive machines are capable of digging, trenching, back-filling and material handling in an extensive range of applications.
  - ***Multi-terrain-*** designed to deliver extremely low ground pressure and features a rubber track system capable of traveling over challenging terrains and underfoot conditions.
  - ***Skid steer-*** used in agriculture, construction, landscaping, road work and many other industries
  - ***Track-type-*** most powerful and durable types of loaders in construction, tracked models are utilized in the toughest jobs and most rugged ground conditions

- ***Wheeled-*** improve the speed and efficiency of material handling on paved roads and hard and aggressive surface

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Fwheeled-loaders-432zx-19171939762.html&psig=AOvVaw1jNXhV4XnDgm08ObfWyZP5&ust=1626376090059000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLDu9KSh4_ECFQAAAAAdAAAAABAE

Figure 63;- wheeled loaders

- **Bulldozers**
  - ***Crawler-*** heavyweight is great for moving heavy materials from one area to another and have rippers that assist with crushing and clearing dense terrain.
  - ***Wheeled-*** This machine is more maneuverable and also ideal to use for soft or sensitive ground since the tires are gentler than tracks**.**
  - ***Mini/compact-*** great for projects that require more maneuverability and versatility than larger machinery.
- **Trenchers-**
  pieces of earthmoving equipment that use a metal chain with teeth made of high-strength steel to rip into the ground

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.bigrentz.com%2Fhow-to-guides%2F5-uses-trencher&psig=AOvVaw387O8DVMH8kbT4bXpnjf7a&ust=1626376189242000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCMCmycOh4_ECFQAAAAAdAAAAABAD

Figure 64;- trenchers

- **Scrapers-**
  A form of equipment used for earthmoving. Its rear bed has a vertically moveable hopper with a sharp horizontal front edge that cuts into the soil like a carpenter's plane and fills the hopper. When full the hopper is raised, closed, and the scraper transports its load to the fill area for dumping

c) CONCRETING EQUIPMENT

- **Concrete Mixture –**
  - ***Continuous mixers-*** used in massive constructions sites such as, for construction of dams, bridges, etc., which involves the use of large masses of concrete and also requires continuous flow of concrete
  - ***Concrete drum/batch mixers***
    - ✓ ***Drum Mixers types***
      - ***Tilting Drum mixers –***
        have a conical or bowl-shaped drum with vanes inside. These types of mixers are preferable for mixes of low workability and for those containing large sized aggregates.

https://www.google.com/url?sa=i&url=https%3A%2F%2Ftheconstructor.org%2Fconcrete%2Ftypes-of-concrete-mixer-machines%2F20045%2F&psig=AOvVaw0hnAyPVM7XhoiCDmycq_E-&ust=1626376249232000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDB9-Oh4_ECFQAAAAAdAAAAABAJ

Fig. 65- Tilting Drum Mixer

- ***Non-tilting Drum mixers-***
  the mixer is not allowed to tilt and the axis of the mixer is always horizontal. The discharge is done either by inserting a chute into the drum or by reversing the direction of rotation of the drum

https://www.google.com/url?sa=i&url=https%3A%2F%2Ftheconstructor.org%2Fconcrete%2Ftypes-of-concrete-mixer-machines%2F20045%2F&psig=AOvVaw0hnAyPVM7XhoiCDmycq_E-&ust=1626376249232000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDB9-Oh4_ECFQAAAAAdAAAAABAJ

Fig. 66 -Non tilting drum mixer

- ***Reversing drum mixer-***
  the ingredients of concrete rotate in one direction and are discharged from the opposite direction

https://www.google.com/url?sa=i&url=https%3A%2F%2Ftheconstructor.org%2Fconcrete%2Ftypes-of-concrete-mixer-machines%2F20045%2F&psig=AOvVaw0hnAyPVM7XhoiCDmycq_E-&ust=1626376249232000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDB9-Oh4_ECFQAAAAAdAAAAABAJ

Fig. 67 – Reversing drum Mixer

- ✓ ***Pan mixers-***
  consists of cylindrical pan that contains set of blades which mix the concrete ingredients. Generally, the mixture of concrete is discharged from the bottom of the pan.

https://www.google.com/url?sa=i&url=https%3A%2F%2Ftheconstructor.org%2Fconcrete%2Ftypes-of-concrete-mixer-machines%2F20045%2F&psig=AOvVaw0hnAyPVM7XhoiCDmycq_E-&ust=1626376249232000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDB9-Oh4_ECFQAAAAAdAAAAABAJ

Figure 68 - Pan mixers

d) COMPACTING EQUIPMENT

- ➢ ***Pad-foot or tamping-***
  Used for compacting dirt. The drum foot roller has a lot of bumps and knobs
- ➢ ***Smooth-drum vibratory rollers-***

- ***The tandem/double drum roller-***

The tandem, or double drum roller, has one steel drum in the front and one in the back. As the two drums move, this moves the roller. The efficiency of the tandem roller comes from the two drums — entire sections of a highway can be flattened and paved quickly and efficiently.

https://www.bigrentz.com/blog/types-of-rollers

fig. 69Double Drum or Tandem Roller

- ***single drum / Three-wheeled rollers*** –

It has a steel drum in the front and two special wheels in the back that can prevent most flat tires from happening.
They're great for creating foundations for buildings and paving highways or sidewalks, but because of the extra weight in the front, they won't roll over some surfaces.

https://www.bigrentz.com/blog/types-of-rollers

Fig. 70 -single Smooth -Drum Roller

- ***Walk-behind vibratory roller-***

One type of walk-behind roller is a cylindrical roller. These ones are traditional in that they are relatively lightweight and are pushed by a person. It is powered by an engine. Cylindrical rollers are used mainly for small and private projects, like yard work.

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FDifferent-types-of-compactors-a-Pad-foot-or-tamping-foot-roller-b-Smooth-drum_fig1_301608399&psig=AOvVaw3-2MG1tN2jzisS3446r-Fm&ust=1626376302485000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCND5zPmh4_ECFQAAAAAdAAAAABAD

Fig. 71- Walk- behind Vibratory roller

- ***Jumping-jack tamper/rammer –***

  A machine used for compacting ground. It applies consecutive impacts on the ground to level the uneven surface,

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FDifferent-types-of-compactors-a-Pad-foot-or-tamping-foot-roller-b-Smooth-drum_fig1_301608399&psig=AOvVaw3-2MG1tN2jzisS3446r-Fm&ust=1626376302485000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCND5zPmh4_ECFQAAAAAdAAAAABAD

Figure 72- Tamper Rammer

e) BITUMEN LAYING EQUIPMENT

Pavers –

Piece of construction equipment used to lay asphalt on roads, bridges, parking lots and other such places.

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Figure 73;- pavers

f) MATERIAL HANDLING EQUIPMENT

- **Crane-**
  used both to lift and lower materials and to move them horizontally. It is mainly used for lifting heavy things and transporting them to other places.
- **Conveyors –**
  piece of mechanical handling equipment that moves heavy or bulky materials from one location to another location**.**

https://www.google.com/url?sa=i&url=http%3A%2F%2Fbasiccivilengineering.com%2F2015%2F05%2Fuse-of-conveyors-materia.html&psig=AOvVaw20HYig9Kn44jjrtbh-

P9qU&ust=1626376442095000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCMDakb-i4_ECFQAAAAAdAAAAABAD

Figure 74;- conveyors

- **Hoists-**
  used on construction sites to vertically transport materials and/or passengers.
- **Forklifts-**
  used to carry hefty building materials over long distances, across the rough terrain.

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.linkedin.com%2Fpulse%2Fsnsc-forklift-3-ton-diesel-fork-lifter-brazil-mariah-snsc&psig=AOvVaw0Rn4DeCyZCulqhZOg-Qebs&ust=1626376492099000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOj9otmi4_ECFQAAAAAdAAAAABAF

Figure 75;- forklifter

g) TRANSPORTING EQUIPMENT

- **Tippers-**
  Trucks used for carrying aggregate, crushed rock, soil and other bulk materials whose contents can be emptied without handling; the front end of the platform can be pneumatically raised so that the load is discharged by gravity

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Ftruck-tipper-12455107673.html&psig=AOvVaw2G8SzgepgvYZ7jz0_5wKEn&ust=1626376573309000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNj47v2i4_ECFQAAAAAdAAAAABAD

Figure 76;- tipper

- **Dumpers-**
  Designed for carrying bulk material, often on building sites.

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.ardenthire.com%2Fblog%2Fthwaites-dumpers-from-ardent%2F&psig=AOvVaw2N27tl_yPRbWqlsj5EmSH4&ust=1626376689373000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOCw4rej4_ECFQAAAAAdAAAAABAE

Figure 77;- dumper

- **Trailers-**
  An unpowered vehicle towed by a powered vehicle. It is commonly used for the transport of goods and materials.
- **Tankers-**
  Designed to carry liquids or gases on roads

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.muayene.com%2Fen%2Fmuayene%2Fbasincli-kaplar-periyodik-kontrolleri%2Fkara-tankeri-periyodik-kontrol-ve-muayenesi&psig=AOvVaw0aqrKqsjMA7kokBksBD_cV&ust=1626376778436000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOicwuSj4_ECFQAAAAAdAAAAABAF

Figure 78-- tanker

h) TUNNELING EQUIPMENT

Road Headers –

Advanced, self-forced and extremely powerful rock cutting machines are designed to excavate roadways, tunnels and compartments continuously without using volatile.

Tunnel Boring Machines (TBM)/"mole"-

A machine assembled using sophisticated types of equipment for excavating tunnels with the help of a variety of soil and rock strata

1.2.6.4 LEARNING ACTIVITIES

a) Practical Activity

i. Identify the equipment below and their uses.

ii. Visit a nearby construction site and identify the equipment utilized and their uses.

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Fig. 79- Construction Equipment

1.2.6.5 Self-assessment test 5

Q1. _____ is a self-propelled machine which is used mainly to exert a powerful tractive force for pulling other machines.

a)Tractor
b)Bulldozer
c)Angle dozer
d) Scraper

Q2. A _____ is very useful equipment and it can be used for construction work like to clear the site of work, to make the land level, etc.

a)Scraper
b)Grader
c)Excavator
d) Bulldozer

Q3. The; size of the bulldozer is indicated by the dimension of its _____

a)Site

b)Tire
c)Engine
d)Blades

Q4. A _____ can be used on wet ground and in all conditions of weather.
a)Grader
b)Scraper
c)Escalator
d) Bulldozer

Q5. A _____ is used to level the ground and spreads the loose material.
a)Excavator
b)Scraper
c)Grader
d) Tractor

1.2.6.6 Tools, Equipment, Supplies and Materials

a) Tools and equipment

- computer
- Hand tools
- Machine tools

b) Materials and supplies

- Computer software
- Construction materials
- Computers
- Stationery
- Manufacturer's catalogues

c) Personal protective equipment (PPEs)

- Safety boots
- Goggles
- Gas masks
- Helmets
- Gloves
- Dust coats
- First aid kit
- Ear muffs
- Dust masks
- Overalls

1.2.6.7 References

Day, D. A., & Benjamin, N. B. (1991). *Construction equipment guide* (Vol. 34). John Wiley & Sons.

Samee, K., & Pongpeng, J. (2016). Structural equation model for construction equipment selection and contractor competitive advantages. *KSCE Journal of Civil Engineering*, *20*(1), 77-89.

Teizer, J., Allread, B. S., & Mantripragada, U. (2010). Automating the blind spot measurement of construction equipment. *Automation in Construction*, *19*(4), 491-501.

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Fwheeled-loaders-432zx-19171939762.html&psig=AOvVaw1jNXhV4XnDgm08ObfWyZP5&ust=1626376090059000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLDu9KSh4_ECFQAAAAAdAAAAABAE

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.bigrentz.com%2Fhow-to-guides%2F5-uses-trencher&psig=AOvVaw387O8DVMH8kbT4bXpnjf7a&ust=1626376189242000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCMCmycOh4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Ftheconstructor.org%2Fconcrete%2Ftypes-of-concrete-mixer-machines%2F20045%2F&psig=AOvVaw0hnAyPVM7XhoiCDmycq_E-&ust=1626376249232000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDB9-Oh4_ECFQAAAAAdAAAAABAJ

https://www.bigrentz.com/blog/types-of-rollers

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FDifferent-types-of-compactors-a-Pad-foot-or-tamping-foot-roller-b-Smooth-drum_fig1_301608399&psig=AOvVaw3-2MG1tN2jzisS3446r-Fm&ust=1626376302485000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCND5zPmh4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FPaver_(vehicle)&psig=AOvVaw1KuCI6SZwqBRc4bJGkYOcx&ust=1626376359253000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCPjD1JKi4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=http%3A%2F%2Fbasiccivilengineering.com%2F2015%2F05%2Fuse-of-conveyors-materia.html&psig=AOvVaw20HYig9Kn44jjrtbh-P9qU&ust=1626376442095000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCMDakb-i4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.linkedin.com%2Fpulse%2Fsnsc-forklift-3-ton-diesel-fork-lifter-brazil-mariah-snsc&psig=AOvVaw0Rn4DeCyZCulqhZOg-Qebs&ust=1626376492099000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOj9otmi4_ECFQAAAAAdAAAAABAF

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Ftruck-tipper-12455107673.html&psig=AOvVaw2G8SzgepgvYZ7jz0_5wKEn&ust=1626376573309000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNj47v2i4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.ardenthire.com%2Fblog%2Fthwaites-dumpers-from-ardent%2F&psig=AOvVaw2N27tl_yPRbWqlsj5EmSH4&ust=1626376689373000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOCw4rej4_ECFQAAAAAdAAAAABAE

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.muayene.com%2Fen%2Fmuayene%2Fbasincli-kaplar-periyodik-kontrolleri%2Fkara-tankeri-periyodik-kontrol-ve-muayenesi&psig=AOvVaw0aqrKqsjMA7kokBksBD_cV&ust=1626376778436000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCOicwuSj4_ECFQAAAAAdAAAAABAF

https://www.google.com/url?sa=i&url=https%3A%2F%2Fpd-training.co.uk%2Fplant-equipment-training%2F&psig=AOvVaw1dE9kCssWWggbyExF1RbgP&ust=1626376939245000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLCx27ik4_ECFQAAAAAdAAAAABAE

1.2.6.8 Responses to self-assessment test 5

Q1. A
Q2. D
Q3. D
Q4. D
Q5. C

1.2.6 Learning outcome 6; TESTING OF BUILDING MATERIALS

1.2.6.1 Introduction to learning outcome

This learning outcome specifies the content of competencies required to Test construction materials. It includes; Materials testing parameters (i) Destructive tests (ii) Non-destructive tests, Materials testing procedures and Quality assurance and control.

1.2.6.2 Performance standards

6.1 Construction materials are sampled randomly as per SOPs.

6.2 Test parameters are identified as per the construction requirements and Engineer's instructions.

6.3 Construction materials are tested as per the SOPs.

1.2.6.3 Information sheet

a) Definition of terms

- **Destructive tests** –
  undertaken in order to understand a specimen's performance or material behavior, these procedures are carried out to the test specimen's failure.
- **Aggressive environment testing** –
  includes fracture and fatigue testing in sour (H2S), sweet (CO2) and other corrosive environments; at a range of temperatures and pressures. These tests allow industry to assess the impact of these conditions on materials and performance.
- **Corrosion testing –**
  This covers non-toxic, small-scale, aqueous corrosion testing in a variety of different environments including fresh and sea water.
- **Fracture and mechanical testing –**
  This includes different types of destructive testing methods such as tension tests, bend tests, Charpy impact tests, Pellini drop weight testing, peel tests, crush testing, pressure and fracture testing.
- **Fatigue testing –**
  Performed in air or seawater environments, these tests are used to test parent materials and the endurance of welded joints under constant or variable amplitude loading. This destructive testing method can also be used for fatigue crack growth testing of welds, base metals, and heat affected zones.
- **Residue stress measurement –**
  a type of testing covers materials with a risk of corrosion from exposure to hydrogen. These tests can be carried out at a variety of different How to write a laboratory report. The following arrangement of the report is suggested: Title This should indicate the nature of the test and the specifications number used. Scope of the test: A brief statement of the purpose and significance of the test should be indicated. Materials: The materials used or tested should be described. Apparatus and method of testing: Special equipment used should be briefly described. The testing procedure should be also described. Data and results of the test: All laboratory data shall be submitted in tabular form. Observations relating to the behavior of the materials should be included. All equations or formulas used should be clearly indicated. Calculations should

be properly checked. The results of the test should be summarized in tabular or graphical form. Discussion There should be included a brief discussion in which attention is drawn to the silent facts shown by the tables and diagrams.

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Figure 80;redidue test

b) Destructive and non -destructive tests

- **Non-destructive methods-:**
  Are mainly used to test strength and investigate its changes over time. Usually samples taken from the structure, and sometimes whole members or structures, are tested in this way. Also load tests, which rather rarely are applied to buildings, but more often to bridges and roads, can be put into this category.
- **Semi-destructive and destructive methods** -:
  are used to test samples and members. They can also be used to test whole structures. Strength and its changes over time are tested, but mainly other properties are tested in this way.

c) How to write a Report

The following arrangement of the report is suggested:

- **Title:**
  This should indicate the nature of the test and the specifications number used. Scope of the test: A brief statement of the purpose and significance of the test should be indicated.
- **Materials:**
  The materials used or tested should be described. Apparatus and method of testing: Special equipment used should be briefly described.
- The testing procedure should be also described.
- **Data and results of the test:**
  All laboratory data shall be submitted in tabular form.
- Observations relating to the behavior of the materials should be included.
- **All equations or formulas:**
  used should be clearly indicated. Calculations should be properly checked. The results of the test should be summarized in tabular or graphical form
- **Discussion**:
  There should be included a brief discussion in which attention is drawn to the silent facts shown by the tables and diagrams. The test results should be compared with the standard values and conclusion should be drawn.

❖ TESTS OF MATERIALS

Reducing Field Sample of Aggregate to Test Sample

- **Purpose:** To obtain laboratory samples of aggregates from stockpiles.

- **Equipment:**
  - Shovel
  - Scoop
  - broom.
- **Procedure:**

(i) Obtain a sample of aggregate (about 50 kg) from three places in the stockpile: from the top third, at the midpoint, and from the bottom third of the volume of the pile.
(ii) Place the field sample on a hard, clean level surface.
(iii) Mix the material thoroughly by turning the entire sample three times.
(iv) Shovel the entire sample into a conical pile.

(v) Carefully flatten the conical to a uniform thickness and diameter by pressing down the apex with a shovel. (The diameter should be approximately four to eight times the thickness).
(vi) Divide the flattened mass into four equal quarters with a shovel.
(vii) Remove two diagonally opposite quarters. Brush the cleared spaces clean.
(viii) Mix and quarter the remaining materials until the sample is reduced to the desired size.

Note; - The sample splitters can be used instead of flattening the mass on a level surface

Fig. (1) The sample splitters for fine &coarse aggregates

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Fig. 81 Sample Splitters

Fig.(2) Reducing Field Sample of Aggregate to Test Sample

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q68017106&psig=AOvVaw1nncM71CuPaGrjBcsYFnGw&ust=1626377211653000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCIjYnLCl4_ECFQAAAAAdAAAAABAD

Figure 82,spliters,fine and coarse aggregate

- **Test No.1: moisture content of concrete aggregate**
  - ✓ **Test scope**

One of the properties of the aggregates which should be known to design a concrete mix is its moisture content in order to determine the net water -cement ratio in a batch of concrete made with job aggregate.

- ✓ **Materials:**

The amount of materials depends on the nominal maximum size of aggregate as follows:

Nms. (mm)	weight of sample(kg)
4.75	0.5
9.5	1.5
12.5	2
19	3
25	4

- ✓ **Apparatus:**
  - A balance sensitive to 0.5gm.
  - Electrical oven at temperature 105 °C.
  - Container with a cover.
  - Sample splitter.

- ✓ **Procedure:**
  - Prepare the container clean, record its empty weight (A).
  - Weigh the suitable sample of aggregate and keep it in a container, put the cover on.
  - The weight of the container with the cover and the gravel is (B).
  - Remove the cover, then put the sample in the oven at 105 °C for 24 hours.
  - Remove the sample forms the oven and put the cover on it, then leaves it for half an hour, and then weigh it (D).
  - Repeat the same steps for the sand sample.

✓ **Calculations and Results**:

Moisture Content % = [(B – D) / (D – A)] x 100

✓ **Discussion:**

- Comment on the results you get.
- Do you think that your results are affected by the weather conditions?

➢ **Test NO 2; - Specific Gravity and Absorption of Coarse Aggregate**

✓ **Scope:**

This test method covers the determination of Specific Gravity and Absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity, bulk specific gravity SSD or apparent specific gravity. The bulk specific gravity and absorption are based on aggregate after 24hour soaking in water.

✓ **Materials:**

Coarse aggregate, must be sampled using sample splitter.

The weight of the sample depends on nominal maximum size (NMS) of the aggregate as follows.

N.M.S(mm)	Minimum weight of samples (kg)
12.5 or less	2
19	3
25	4
37.5	5
50	8

✓ **Apparatus**

- A weighing balance - sensitive, readable and accurate to 0.5gm.
- The balance shall be equipped with suitable apparatus for suspending the sample container in water.
- Sample container (A wire basket) [20cm diameter& 20cm in height].
- Water tank; a watertight tank into which the sample container may be placed while suspended below the balance.
- Sieves; 4.75mm (No.4) or other sizes as needed

✓ **Procedure:**

- Take the sample of coarse aggregate using the sample splitter.
- Sieve the sample with 4.75mm sieves and ignore the materials passing through No.4.75 sieve. - Wash the sample to remove dust.

- Put the sample in the oven at 105°C.for 24hours.
- Get the sample out of the oven, leave it to cool then determine its weight.
- Submerge the sample in water for 24hours.
- Remove the sample from the water and roll it in a large absorbent cloth until all visible films of water are removed .Wipe the larger particles individually. Take care to avoid evaporation of water from aggregate pores during the operation of surface- drying.
- Take the required weight of the sample in its (S.S.D) (saturated surface dry) condition.
- After weighing, immediately place the S.S.D sample in the sample container and determine its weight in water at 23±1°C.Take care to remove all entrapped a before weighing by shaking the container while immersed.
- Dry the test sample to constant weight at a temperature of 110±5°C, Cool in air at room temperature 1 to 3 hours, or until the aggregate has cooled to a temperature that is comfortable to handle, and weigh.

✓ **Calculations: -**

1-Specific Gravity:-

- ***Bulk specific gravity*** = A /(B-C)
  Where:
  A=Weight of oven-dry test sample in air, (gm).
  B= Weight of S.S.D. sample in air, (gm).
  C=Weight of saturated sample in water, (gm).
- ***Bulk Specific Gravity (SSD)*** = B / (B-C)
- ***Apparent Specific gravity:*** -
  Calculate the apparent sp. gr. As follows:
  Apparent Specific Gravity = A / (A - C)
- ***Absorption:-***
  Calculate the percentage of absorption as follows:
  Absorption % = [(B – A) / A] x100

  Compare the results with the typical values.
  How can the percentage of absorption affect a concrete mix?

➢ **Test No 3;- the slump of hydraulic cement concrete**

✓ **Scope :**

This test method is used to determine the slump of freshly mixed concrete, which is an approximate measure of consistency. The test may be done in the laboratory and in field. :

✓ **Apparatus:**

Weights and weighing device.
Tools and containers for mixing, or concrete mixer

Tamper (16 mm in diameter and 600 mm length)
Ruler
Slump cone which has the shape of a frustum of a cone with the following dimensions:

- Base diameter 20 cm
- Top diameter 10 cm
- Height 30 cm
- Materials thickness at least 1.6 mm

✓ **Procedure:**

(i) Prepare a clean, wide, flat mixing pan.

(ii) Place the dampened slump cone on one side of the pan. It shall be held firmly in place during filling by the operator standing on the two-foot pieces.

(iii) Place the newly mixed concrete (prepared as in test No. 3) in three layers, each approximately one third the volume of the mold.

(iv) In placing each scoopful of concrete, move the scoop around the top edge of the mold as the concrete slides from it, in order to ensure symmetrical distribution of concrete within the mold.

(v) Rod each layer with 25 strokes of the tamper, distribute the strokes in a uniform manner over the cross section of the mold, each stroke just penetrating into the underlying layer. 6-For the bottom layer this will necessitate inclining the rod slightly and making approximately half of the strokes spirally toward the center. Rod the bottom layer throughout its depth.

(vi) In filling and rodding the top layer, heap the concrete above the mold before rodding is started.

(vii) After rodding the top layer, strike off the surface of the concrete with a trowel, leaving the mold exactly filled.

(viii) While filling and rodding, be sure that the mold is firmly fixed by feet and can't move.

(ix) Clean the surface of the base outside the cone of any excess concrete. Then immediately remove the mold from the concrete by raising it slowly in a vertical direction.

(x) Measure the slump immediately by determining the difference between the height of the mold and the height of the vertical axis (not the maximum height) of the specimen.

(xi) Clean the mold and the container thoroughly immediately after using.

(xii) If the pile topples [when raising the mold out of concrete] sideways, it indicates that the materials have not been uniformly distributed in the mold and the test should be remade.

(xiii) Clean the mold and the container thoroughly immediately after using.

(xiv) If the pile topples [when raising the mold out of concrete] sideways, it indicates that the materials have not been uniformly distributed in the mold and the test should be remade.

Fig.(8) Measuring the slump.

Fig. (9) Different possible slump test results.

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Figure 83; different slump sizes

- **Test No.4; - splitting tensile strength of cylindrical concrete specimens**

  - ✓ **Scope:**
    This method covers the determination of the splitting tensile strength of cylindrical concrete specimens.

  - ✓ **Apparatus:**
    - Weights and weighing device.
    - Tools, containers and pans for carrying materials & mixing.
    - A circular cross-sectional rod (φl6mm & 600mm length).
    - Testing machine.
    - Three cylinders (φ150mm & 300mm in height).
    - A jig for aligning concrete cylinder and bearing strips.

  - ✓ **Procedure:**
    (i) Prepare three cylindrical concrete specimens following same steps as test No.3
    (ii) After molding and curing the specimens for seven days in water, they can be tested.
    (iii) Two bearings strips of nominal (1/8 in i.e. 3.175mm) thick plywood, free of imperfections, approximately (25mm) wide, and of length equal to or slightly longer than that of the specimen should be provided for each specimen.
    (iv) The bearing strips are placed between the specimen and both upper and lower bearing blocks of the testing machine or between the specimen and the supplemental bars or plates.

(v) Draw diametric lines an each end of the specimen using a suitable device that will ensure that they are in the same axial plane. Center one of the plywood strips along the center of the lower bearing block.

(vi) Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and centered over the plywood strip.

(vii) place a second plywood strip lengthwise on the cylinder, centered on the lines marked on the ends of the cylinder.

(viii) Apply the load continuously and without shock, at a constant rate within, the range of 689 to 1380 kPa/min splitting tensile stress until failure of the specimen.

(ix) Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and appearance of fracture.

✓ **Computations:**

Calculate the splitting tensile strength of the specimen as follows:

$T = 2P$ divided by πLd

Where:

T: splitting tensile strength, kPa

P: maximum applied load indicated by testing machine, kN

L: Length, m d: diameter, m

➢ **Test No 5; - compressive strength of cylindrical concrete specimens**

✓ **Scope:**

The test method covers the determination of compressive strength of cylindrical concrete specimens, such as molded cylinders and drilled cores. It is limited to concrete having a unit weight > 800 kg/m3

✓ **Apparatus:**

- Weights and weighing device.
- Tools and containers and pans for mixing, or mixer.
- A tamper (circular in cross-section) (16 mm in diameter and 600 mm in length).
- Testing machine.
- Three cylinders (150mm in diameter and 300mm in height).
-

✓ **Procedure:**

(i) Follow the same steps as in .(test No. 3) in order to prepare a fresh concrete mix.

(ii) The cylinder also must be clean, lightly oiled, well fixed with the base.

(iii) Filling the specimens will be also in three layers, roding each layer by (25) strokes using the circular section rod.

(iv) All other steps are the same as in test No. 6. The test specimens must be tested in the moist condition with a rate of loading (0.14-0.34) MPa.

✓ **Calculations:**

Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-section area .
If the specimen length to diameter ratio is less than(1.8), correct the result obtained by multiplying the appropriate correction factor shown in following table:

L.D	1.75	1.5	1.25	1
FACTOR	0.96	0.98	0.93	0.87

Note; Factor are applicable for normal concrete strengths (from13.8-14.4) MPa

- **Test No.9; - splitting tensile strength of cylindrical concrete specimens**

  - ✓ **Scope:**
    This method covers the determination of the splitting tensile strength of cylindrical concrete specimens.

  - ✓ **Apparatus:**
    - Weights and weighing device.
    - Tools, containers and pans for carrying materials & mixing.
    - A circular cross-sectional rod (φl6mm & 600mm length).
    - Testing machine.
    - Three cylinders (φ150mm & 300mm in height).
    - A jig for aligning concrete cylinder and bearing strips.

  - ✓ **Procedure:**
    (i) Prepare three cylindrical concrete specimens following same steps as test No.3. After molding and curing the specimens for seven days in water, they can be tested.
    (ii) Two bearings strips of nominal (1/8 in i.e., 3.175mm) thick plywood, free of imperfections, approximately (25mm) wide, and of length equal to or slightly longer than that of the specimen should be provided for each specimen.
    (iii) The bearing strips are placed between the specimen and both upper and lower bearing blocks of the testing machine or between the specimen and the supplemental bars or plates.
    (iv) Draw diametric lines each end of the specimen using a suitable device that will ensure that they are in the same axial plane. Center one of the plywood strips along the center of the lower bearing block.
    (v) Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and centered over the plywood strip.
    (vi) Place a second plywood strip lengthwise on the cylinder, centered on the lines marked on the ends of the cylinder.
    (vii) Apply the load continuously and without shock, at a constant rate within, the range of 689 to 1380 kPa/min splitting tensile stress until failure of the specimen.
    (viii) Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and appearance of fracture.

(ix) Without shock, apply and increase the load continuously at a nominal rate within the range of (0.2 N/mm2.s to 0.4 N/mm2.s) until no greater load can be sustained. On manually controlled machines, as failure is approached, the loading rate will decrease; at this stage operate the controls to maintain, as far as possible, the specified loading rate.

(x) Record the maximum load applied to each cube

Note: When the cubes are surface dry, or have not been cured in water, immerse them in water.

✓ **Computations:**

Calculate the splitting tensile strength of the specimen as follows:

$$T = 2P / \pi Ld$$

Where:

T: splitting tensile strength, kPa

P: maximum applied load indicated by testing machine, KN

L: Length, m d: diameter, m

Note: This test is not a true tension test, but it fails in tension and is used to indicate the tensile strength of concrete.

Record any unusual feature in the type of failure. Refer for examples of satisfactory and unsatisfactory failures.

NB; - failures are usually caused by insufficient attention to the detail.

Note of making and testing specimens, such as bad molds, bad made specimens or misplacement of cubes in the testing machine or machine fault.

✓ **Calculations:**

Calculate the cross-sectional area of the cube face from the checked nominal dimensions. Calculate the compressive strength of each cube by dividing the maximum load by the cross-sectional area. Calculate the average for the three cubes

➢ **Fire Testing of building materials**

Fire testing generally falls into two categories:

- Tests to measure ignition and the spread of flames from one area to another.
- Tests to measure fire resistance. Fire resistance tests measure a material's ability to continue to serve its structural role during a fire.

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Figure 84;-fire test

- **Abrasion testing**

Abrasion resistance- the process of scraping or wearing something away.

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Figure 85;- abrasion testing

- **Compression testing**

Used to determine how a product or material reacts when it is compressed, squashed, crushed or flattened by measuring fundamental parameters that determine the specimen behavior under a compressive load.

*The **wood** orientated vertically in the apparatus.*

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Figure 86; material subjected to compression

Material subjected to compression

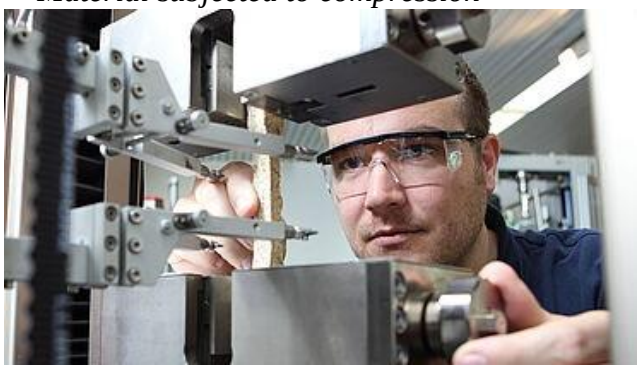

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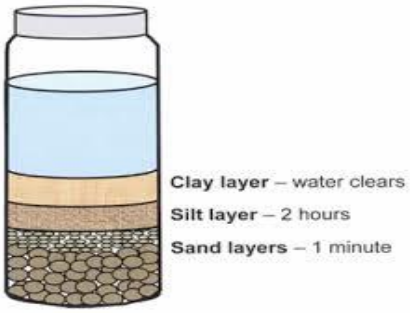
Figure 87;- compression testing

Density - This is the mass per unit volume of a material or the degree of compactness of a substance.

Hardness - resistance of a mineral to scratching

- **Test of Impurities**

a. Test of impurities in fine aggregates



https://civilblog.org/2016/02/29/how-to-check-impurities-in-sand-on-site/

Figure 88;- test of impurities

A simple and widely-used **test** that is used for detecting deleterious **organic** materials in **fine aggregates**. Samples are mixed in a special graduated colorless glass bottle with a 3% sodium hydroxide solution, then allowed to stand for 24 hours.

NB;- **Organic impurities** include impurities already present in the raw materials, isomeric colorants, subsidiary colorants, decomposition compounds, compounds formed from side reactions, and chance contaminants.

❖ TESTING OF MORTARS

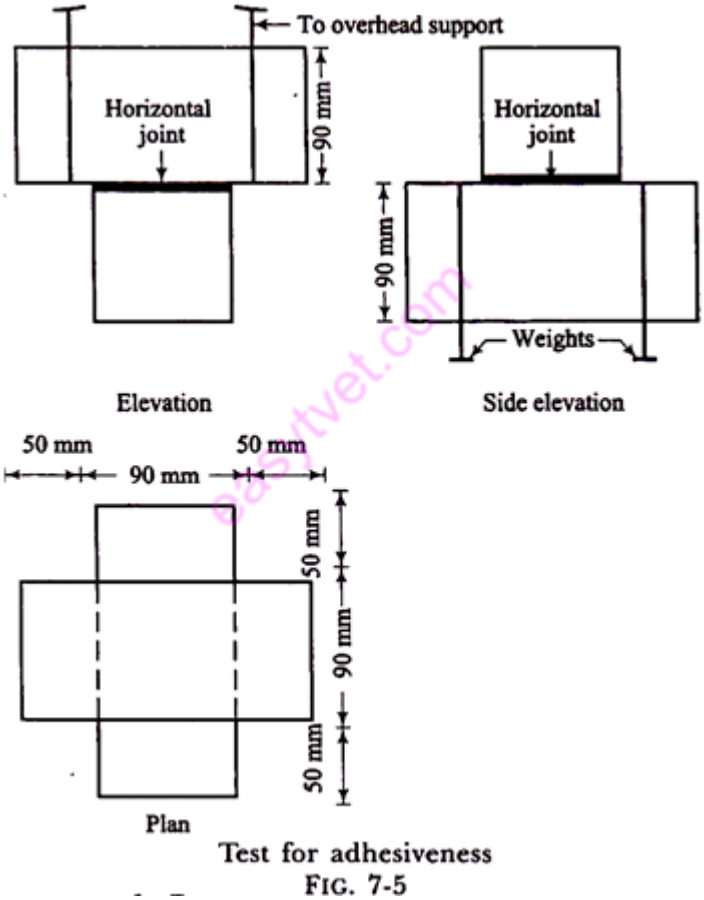
The mortars are tested for their quality by their;

- ✓ Adhesiveness to building units.
- ✓ Crushing strength.
- ✓ Tensile strength.

➢ Adhesiveness to Building Units Test:

Following procedure is adopted to carry out this test:

(i) The two bricks are placed at right angles to each other as shown in fig. 7-5.



Test for adhesiveness

FIG. 7-5

https://www.engineeringenotes.com/engineering-materials-2/mortar/mortar-classification-properties-preparation-and-uses-engineering-materials/46507

Fig. 89- Test for Adhesiveness

(ii) The mortar is placed to join them so as to form a horizontal joint. If size of bricks is 190 mm x 90 mm x 90 mm, a horizontal joint of 90 mm x 90 mm = 810 mm^2 will be formed.

(iii) The upper brick is suspended from an overhead support and the weights are attached to the lower brick.

(iv) The weights are gradually increased till separation of bricks occurs.
(v) The ultimate adhesive strength of mortar per mm^2 area is obtained by dividing maximum load with 810.

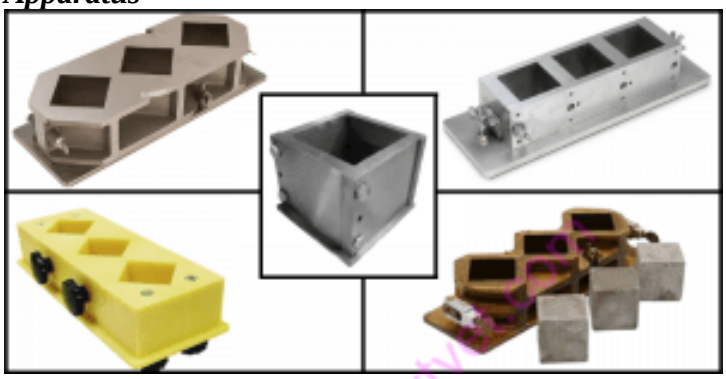
➢ Crushing Strength Test:

For this test, the brickwork is carried out with mortar to be tested. A sample of this brickwork is taken and it is gradually loaded in a compression testing machine till failure occurs due to crushing. The ultimate crushing strength is obtained by dividing maximum load with cross-sectional area.

- ***Determination of Compressive Strength of Mortar:***

To find the compressive strength of cement standard sand mortar cubes, the following would be the procedure and apparatus on the test.

Apparatus



https://civiljungle.com/test-of-mortar/

fig.90- Mortar Cube Size 7.06 cm x 7.06 cm x 7.06 cm

https://civiljungle.com/test-of-mortar/

fig.91- Apparatus for Gauging and Mixing Mortar

https://civiljungle.com/test-of-mortar/

fig.92- Vibrator for Morta Cube

https://civiljungle.com/test-of-mortar/

fig.93 Compression Testing Machine

Process for Compressive Strength of Mortar.

(i) Take 200gm of cement and 600gm of sand in the mix ratio 1:3 by weight in a pan.

(ii) The standard sand will be of walnut, of light, grey or whitish variety and will be free of silt.

(iii) The sand grains will soon be angular, the shape of grains approximating into the spherical form, elongated and flattened grains being present only in very small quantities.

(iv) Standard sand will pass through 2 mm IS sieve and will be retained on 90 microns IS sieve using the following particle size distribution.

(v) Mix the cement and sand in dry condition using a trowel to get one minute and then add water.

(vi) The quantity of water will be (p/4+3)% of the combined weight of cement and sand, where p is the % of the water required to produce a paste of standard consistency determined earlier.

(vii) Add water and mix it until the mixture is of uniform colour.

(viii) The time of mixing shall not be < 3 minutes & not > 4 minutes.

(ix) Immediately after mixing the mortar, then place the mortar at the cube mold and prod with the help of the rod.

(x) The mortar will be prodded 20 times in about 8 sec to ensure the elimination of entrained air.

(xi) If the vibrator is used, the period of vibration will be two minutes in the specified speed of 12000±400 vibrations /minutes.

(xii) Then place the cube molds in temp. of 27±2° C and 90% relative humidity for 24 hours.

(xiii) After 24 hours, remove the cubes in the mould and immediately submerge in clean water till testing.

(xiv) Take out the cubes from the water just before testing. Testing needs to be done on their sides without any packing.

(xv) The rate of loading needs to be 350 kg/cm^2/minute and uniform.

(xvi) A test ought to be conducted for 3 cubes and report the average value as the test result for both 7day and 28-day compressive strength.

Result of Mortar Cube Test

Compressive strength at 7 days =…….N/mm^2

Compressive strength at 28 days =…….N/mm^2

➢ Tensile Strength Test:

This test was formerly used to have an indirect indication of compressive strength of cement. It is at present generally used for the rapid hardening cement.

Following procedure is adopted:

(i) The mortar of cement and sand is prepared. The proportion is 1:3 which means that x gm of cement is mixed with 3x gm of sand.

(ii) The water is added to the mortar. The quantity of water is 8 per cent by weight of cement and sand.

(iii) The mortar is placed in briquette moulds. A typical briquette is shown in fig. 6-7. The mould is filled with mortar and then a small heap of mortar is formed at its top. It is beaten down by a standard spatula till water appears on the surface. Same procedure is repeated for the other face of briquette. Such twelve standard briquettes are prepared. The quantity of cement may be 600 gm for 12 briquettes.

(iv) The briquettes are kept in a damp cabin for 24 hours.

(v) The briquettes are carefully removed from the moulds and they are submerged in clean water for curing.

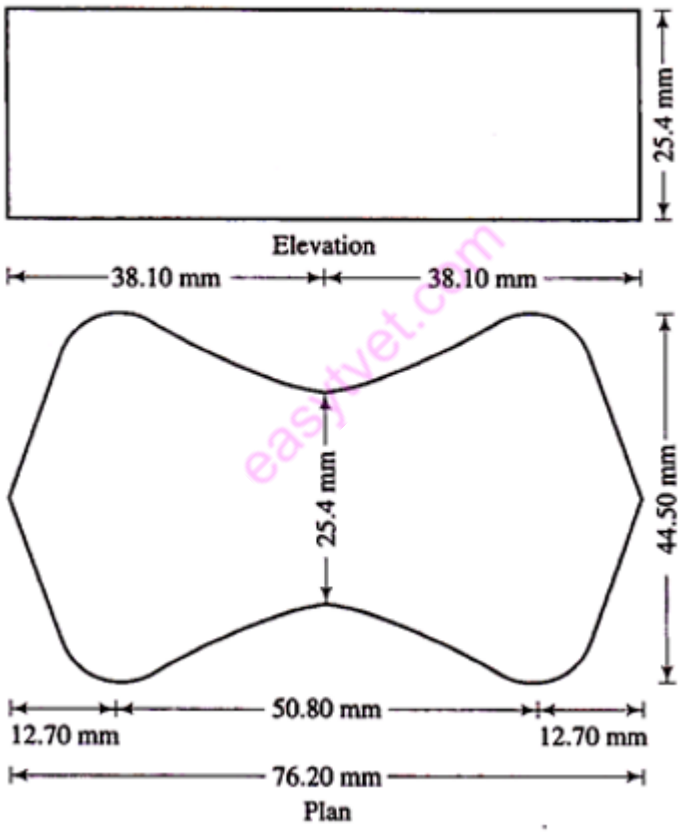
(vi) The briquettes are tested in testing machine at the end of 3 days and 7 days. Six briquettes are tested in each test and average is found out. During the test, the load is to be applied uniformly at the rate of 35 kg/cm^2 or 3.50 N/mm^2.

(vii) It may be noted that cross-sectional area of briquette at its least section is 6.45 cm^2. Hence the ultimate tensile stress of cement paste is obtained from the following relation –

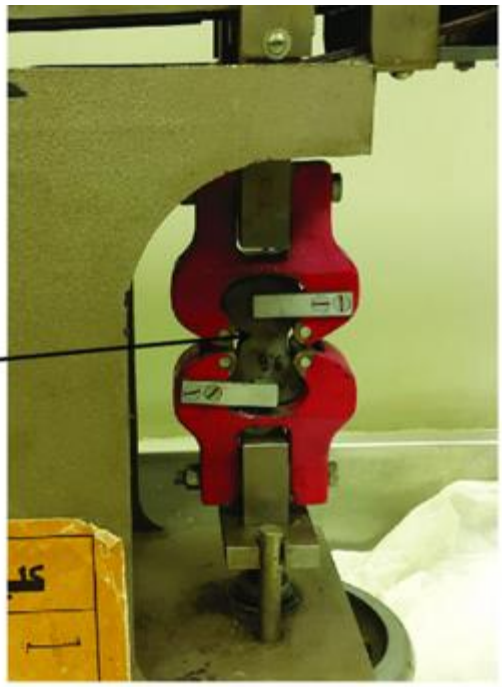
$$\text{Ultimate tensile stress} = \frac{\text{failing load}}{6.45}.$$

(viii) The tensile stress at the end of 3 days should not be less than 20 kg/cm^2 or 2 N/mm^2 and that at the end of 7 days should not be less than 25 kg/cm^2 or 2.50 N/mm^2.

https://www.aiclabequipments.com/productDetails.php?catid=17&subid=227
fig. 94- Briquette moulds – Single Gang



https://www.engineeringenotes.com/concrete-technology/cement-concrete-technology/how-to-test-and-check-the-quality-of-the-cement/46482
Fig. 95- Standard Briquette



https://www.researchgate.net/figure/Testing-of-cement-mortar-specimens-a-cube-under-compression-test-b-briquette-under_fig9_290542276

Fig. 96- Briquette testing machine

1. QUALITY ASSURANCE AND CONTROL

(i) Quality and Safety Concerns in Construction

- Defects or failures in constructed facilities can result in very large costs.
- Even with minor defects, re-construction may be required and facility operations impaired.
- Increased costs and delays are the result.
- In the worst case, failures may cause personal injuries or fatalities. Accidents during the construction process can similarly result in personal injuries and large costs.
- Indirect costs of insurance, inspection and regulation are increasing rapidly due to these increased direct costs.

NB; - Good project managers try to ensure that the job is done right the first time and that no major accidents occur on the project.

(ii) Organizing for quality safety

A variety of different organizations are possible for quality and safety control during construction e.g.

- Have a group responsible for quality assurance
- Another group primarily responsible for safety within an organization.

NB; - In large organizations, departments dedicated to quality assurance and to safety might assign specific individuals to assume responsibility for these functions on particular projects.

(iii) Work and material specification

- Specifications of work quality are an important feature of facility designs.
- Specifications of required quality and components represent part of the necessary documentation to describe a facility.
- Typically, this documentation includes any special provisions of the facility design as well as references to generally accepted specifications to be used during construction.

(iv) Quality control

Quality control in construction typically involves insuring compliance with minimum standards of material and workmanship in order to insure the performance of the facility according to the design.

For the purpose of insuring compliance, random samples and statistical methods are commonly used as the basis for accepting or rejecting work completed and batches of materials.

NB; - Rejection of a batch is based on non-conformance or violation of the relevant design specifications.

Procedures for this quality control practice:

➢ **Quality control by statistical method**

- An ideal quality control program might test all materials and work on a particular facility e.g. the use of non-destructive techniques such as x-ray inspection of welds throughout a facility.
- An on-site inspector can witness the appropriateness and adequacy of construction methods at all times.
- Exhaustive or 100% testing of all materials and work by inspectors can be exceedingly expensive and, in most instances, requires the destruction of a material sample hence so exhaustive testing is not even possible.
- As a result, small samples are used to establish the basis of accepting or rejecting a particular work item or shipment of materials. Statistical methods are used to interpret the results of test on a small sample to reach a conclusion concerning the acceptability of an entire *lot* or batch of materials or work products.

1.2.6.4 LEARNING ACTIVITIES

a) Practical activity

You are provided with different construction materials

- Identify the tests to carry out on each material.
- Identify the procedures of carrying out the following tests on the materials
  - Compression test
  - Abrasion test
  - Fire test
  - Water absorption test
  - Impurity test

1.2.6.5 Self-assessment test 6

Q1. The application of asphalt to basements in order to prevent penetration of water is described as:

(a) flaunching
(b) tanking
(c) benching
d) haunching

Q2. The usual test for the workability of concrete is the:

(a) compression test
(b) sieve test
(c) silt test
(d) slump test

Q3. Bricks that are subjected to severe weather conditions should be:

(a) permeable
(b) porous
(c) dense
(d) sulphate resisting

Q4. Curing of concrete is achieved by providing:

(a) cold surface conditions
(b) constant hot air
(c) intermittent surface heat
(d) damp conditions

Q5. Plasticizers used in mortars increase:

(a) strength
(b) density
(c) adhesion
(d) workability

1.2.6.6 Tools, Equipment, Supplies and Materials

a) Tools and equipment

- computer
- Hand tools

- Machine tools

b) Laboratory testing equipment

- Laboratory apparatus
- Materials and supplies
- Computer software
- Construction materials
- Computers
- Stationery
- Manufacturer's catalogues

c) Personal protective equipment (PPEs)

- Safety boots
- Goggles
- Gas masks
- Helmets
- Gloves
- Dust coats
- First aid kit
- Ear muffs
- Dust masks
- Overalls

1.2.6.7 References

Ang, A.H.S. and W.H. Tang, *Probability Concepts in Engineering Planning and Design: Volume I - Basic Principles*, John Wiley and Sons, Inc., New York, 1975.

Au, T., R.M. Shane, and L.A. Hoel, *Fundamentals of Systems Engineering: Probabilistic Models*, Addison-Wesley Publishing Co., Reading MA, 1972

MaterialsScience2000 (2013 Jan 27)*Tensile Tests [video]. YouTube.* https://www.youtube.com/watch?v=D8U4G5kcpcM

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.businesswire.com%2Fnews%2Fhome%2F20150601005454%2Fen%2FStart-to-Finish-Workflows-Designed-to-Increase-Productivity-for-Pesticide-Residue-Testing&psig=AOvVaw0dQLa8bZlLALuFDamPJM1S&ust=1626377152005000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCNDAgo-l4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.chegg.com%2Fhomework-help%2Fquestions-and-answers%2Faggregate-sieve-analysis-scope-test-aggregate-sieve-analysis-covers-determination-particle-

q68017106&psig=AOvVaw1nncM71CuPaGrjBcsYFnGw&ust=1626377211653000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCIjYnLCl4_ECFQAAAAAdAAAAABAD

https://www.google.com/url?sa=i&url=https%3A%2F%2Fcivilseek.com%2Fconcrete-slump-test%2F&psig=AOvVaw1_c9L4mlCtu22hNSWF75Wh&ust=1626377293503000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCLC4vdql4_ECFQAAAAAdAAAAABAG

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.teslarati.com%2Fspacex-starship-raptor-orbital-duration-test-fire%2F&psig=AOvVaw2R-a6xV--PcEXzxopnpjfF&ust=1626377402533000&source=images&cd=vfe&ved=0CAoQjRxqFwoTCICHk4um4_ECFQAAAAAdAAAAABAF

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https://civilblog.org/2016/02/29/how-to-check-impurities-in-sand-on-site/

https://www.engineeringenotes.com/engineering-materials-2/mortar/mortar-classification-properties-preparation-and-uses-engineering-materials/46507

https://civiljungle.com/test-of-mortar/

https://www.aiclabequipments.com/productDetails.php?catid=17&subid=227

https://www.engineeringenotes.com/concrete-technology/cement-concrete-technology/how-to-test-and-check-the-quality-of-the-cement/46482

https://www.researchgate.net/figure/Testing-of-cement-mortar-specimens-a-cube- under-compression-test-b-briquette-under_fig9_290542276

1.2.6.8 Responses to self-assessment test 6

Q1 B
Q2 D
Q3 C
Q4 D
Q5 D

1.2.7 Learning outcome 7: HANDLE CONSTRUCTION MATERIALS SAFELY

1.2.4.9 Introduction to learning outcome

This learning outcome specifies the content of competencies required to Handle construction materials safely. It includes; User safety in handling construction materials and Construction Materials handling and storage.

1.2.5 Performance standards

1.1 Construction materials to be handled are identified.
1.2 Safety requirements are identified based on the construction materials.
1.3 Construction materials are handled safely based on the safety requirements.

1.2.6 Information sheet

a) Definition of terms

- **Personal protective equipment –**
  PPEs are equipment worn by workers to minimize exposure to hazards that cause serious workplace injuries and illnesses which may result from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazard
- **Safety –**
  The condition of being protected from or unlikely to cause danger, risk, or injury**.**
- **Cryogenic-**
  These are liquids such as nitrogen, helium, hydrogen, argon, methane, and carbon monoxide that have boiling points below minus 130^{o} F (minus 90^{o} C).

b) User safety in handling construction materials

Material handling is performed by almost every worker in the workforce as sole duty or part of regular work conducted in every department, warehouse, office, or facility of a company.

Material handling can be conducted either by hand or with mechanical help.

NB; although mechanical handling creates a new set of hazards, the net result is;

- Fewer injuries.
- lower workers' compensation expenses.
- to higher efficiency and productivity at lower cost.

c) Preventing Common Injuries

Handling of material accounts for 20% to 45% of all occupational injuries. The most common forms of injuries include;

- Strains.
- Sprains fractures.
- Contusions.

NB; Injuries can occur in any part of the operation and are not limited to stockroom or warehouse.

To gain insight into the injuries caused by materials handling, the safety professional should consider the following:

- Can the job be engineered to eliminate or reduce manual handling?
- Can the material be conveyed or moved mechanically?
- Would protective clothing prevent injuries?

- Can employees be given handling aids?
- Would training and more effective management help reduce injuries?

d) Personal protection

(i) Hazard assessment

- ***Manual Lifting:***

  Manual lifting and other activities such as lowering, pushing, pulling, carrying material, or twisting the body can cause back injuries. To determine what is safe or unsafe to lift the following factors should be considered in manual lifting:
  - load location
  - task repetition
  - load weight.

- ***Fall Protection:***

  Fall protection measures include the following controls:
  - ✓ elimination of the hazard by reorganizing the work.
  - ✓ prevention of falling by the use of guardrails, including aerial lifts.
  - ✓ fall arrest systems for horizontal and vertical travel.
  - ✓ Warning lines 6 ft. from an edge.

NB;- Hazard assessment should be conducted to determine the required and recommended PPE.

- ***Personal Protective Equipment (P.***P.E)

  Personal protective equipment, or PPE, protects workers from serious workplace injuries or illnesses resulting from physical, electrical, mechanical, chemical, or other workplace hazards. Examples of PPE include hard hats, face shields, goggles, gloves, vests, respirators, safety shoes, and coveralls.
  PPE is required for many transportation maintenance activities. Both employers and employees have responsibilities for maintaining a safe work environment.

http://www.mnltap.umn.edu/topics/workplace/personal_protection_equipment/index.html

Figure 97;- Personal protective Equipment (P.P.E.)

- **Hard hats (helmet)**
  Overhead hoisting operators and maintenance personnel are exposed to fall hazards. The hats protect against head injuries
  NB; hats should be inspected prior to each use and damaged ones should never be worn.

- **Boots**
  They are used to protect against crushed toes due to heavy or falling equipment or materials and should have puncture-resistant, nonslip soles, as work surfaces can have sharp objects on them, and slips are a major hazard at the job site.

- **Work pants and work shirts**
  Workers should protect their full legs, full arms, and torso against cuts, scrapes, burns, and other superficial injuries with thick, flexible work pants and shirts which fit closely and never be baggy.
- **Face shields and safety glasses**
  Face shields should be worn whenever there is a danger of flying debris or harmful dust getting in the eyes. Cutting, grinding, welding, chipping, and nailing are some activities that necessitate protective eyewear
- **Ear plugs /ear muffs**
  Ear plugs should be used to protect against prolonged loud noises due to heavy cutting and grinding machines
- **Gloves**
  heavy-duty leather & canvas gloves- protecting against cuts and burns.
  welding gloves – welders.
  heavy-duty rubber gloves - working with concrete.
  insulated gloves with sleeves - working with electric hazards.
  Chemical-resistant gloves - working with chemical agents.

NB;

Gloves should be dry and free of grease and oil..
Clean, leather-palmed gloves give you a better grip when handling smooth metal objects.
Do not wear gloves near certain machinery such as conveyors or wherever there is a risk of gloves being caught in the machine.

- **Reflective/high-visibility garments**
  Brightly colored and/or reflective jackets, vests, or other upper-body clothing is important for worker visibility

NB;

Where toxic materials are being handled, workers should take daily showers to remove the material from their personal protective gears before they leave the facility.
Encourage workers to wash thoroughly at the end of their shift.
Provide cleaning materials and PPE for workers (suits, caps, coveralls).

e) Construction Materials handling and storage

NB; Manual handling of materials increases the possibility of injury and adds to the product's cost. Thus, minimize manual handling of materials.

➢ **General pointers on how to handle mechanical tools materials**

- Inspect materials for slivers, jagged or sharp edges, burrs, rough or slippery surfaces.
- workers should inspect the object to decide how they will grasp it, thus avoiding sharp edges.
- Grasp objects with a firm grip.
- Keep fingers away from pinch and shear points.
- Wipe off greasy, wet, slippery, or dirty objects before handling them.
- Keep hands free of oil, dirt, or grease.

- **Handling and storing Cryogenic Liquids.**
  - Inspect all incoming containers before storing to ensure they are not damaged and are properly labeled
  - Keep Dewar flasks covered with a loose fitting cap. This method prevents air or moisture from entering the container yet allows pressure to escape.
  - Use only the stopper or plug supplied with the container.
  - Glass Dewar flasks are available but never use them to store combustible or oxidizing cryogenic liquids.
  - Ensure that ice does not form in the neck of flasks to reduce chances of a pressure hazard.
  - Ensure that ignition sources and combustible materials are kept far away from liquefied oxygen and other flammable material storage and handling areas.
  - Do not store liquid oxygen containers on wood, asphalt or oil soaked gravel. Use concrete or clean gravel under storage areas.
  - Store all cryogenic liquid containers upright in well-ventilated areas. Handle them carefully, and avoid dropping, rolling or tipping them on their sides.
  - Use care when loading or unloading by forklift, crane or other power assist devices.
  - Restrict access to storage areas. Allow only authorized people into the storage areas. Clearly post warning signs and emergency instructions.
  - Protect against combustion accelerant, ignition, and electrostatic charge.
  - Train workers on first aid and self-aid techniques for medical emergencies handling emergency situations such as fire, spills, and leaks

- **Precautions in shipping and receiving**
  - Floors, ramps, and aisles must be level strong and in good shape
  - Ramps should have handrails
  - Aisles should be wide enough to enable employees to move freely while handling material and to allow safe passage of loaded equipment.
  - Keep aisles leading to sprinkler valves and fire-extinguishing equipment clear.
  - Keep space around sprinkler head free of materials.
- **Precautions in handling machines and tools.**
  - Machines such as shears, saws, and nailing machines should have protective guards.
  - Workers should always be in their PPEs.
  - Dock boards should be wide enough to permit easy maneuvering of hand or power trucks.
  - Employees must Use only approved materials-handling ladders and never climb racks or shelves.
  - Special precautions should be taken due to wire wrap, glass and nails due to broken glass hazard and flying nails.
  - For barrels, kegs, and drums, Use proper cut resistant gloves and safety goggles.
  - Use proper cutting tool to open construction of boxes and cartons.
- **Maintaining heavy construction equipment**

- **Maintain Operational Records** - outline the protocols involved in servicing each piece of machinery used for construction services, and tracking inspections and repairs, companies help preserve the useful working life of equipment
- **Perform Regular Cleaning** - frequent cleaning of the equipment helps maintenance personnel keep track of the condition of different items much better.
- **Record Fluid Levels** - periodic refills enable maintenance personnel to detect potential operational problems at an early point
- **Perform Regular Lubrication** - helps to preserve the equipment and will extend their lifetime.
- **Protect Electrical Wiring-** cover machinery with a secure protective tarp, or to shelter the equipment under a covering to prevent unnecessary wear and tear on the electrical components
- **Check Tire And Axle Condition** - Additionally, checking the tread and general condition of the dump truck, trailer tires, and axles helps avoid problems in the field.
- **Inspect For Leaks** - owners of this expensive equipment can obtain necessary repairs much faster, by paying attention to possibly leaky valves.
- **Inspect For Misalignment** - assuring proper alignment in heavy machinery remains essential. Scheduling regular inspections to review this issue helps extend the working life of some items of construction equipment.

➢ **Storage and handling equipment**

Tools and equipment have to be appropriately stored when not in used to keep them in shape and avoid certain hazards. Storage and handling equipment are used to help store and monitor tools present.

✓ **Racks** - basic but important method of storage, saving floor space while keeping their contents accessible.
- pallet racks
- drive-through
- drive-in racks
- push-back racks
- sliding racks

✓ **Stacking frames** - stackable like blocks that allow crushable pallets of inventory, such as containers of liquid, to be stacked to save space without damage.

Shelves, bins, and drawers. Shelves are less open than racks and are used with bins and drawers. They're more able to keep smaller and more difficult to manage materials and products stored and organized.
- Boltless shelves
- Cantilever shelves
- Revolving shelves
- tie-down shelves

✓ **Mezzanines**- an indoor platform, help to create more floor space in a warehouse or other storage building for offices or more storage.
- Modular
- Movable

- rack supported
- building supported
- Free-standing versions.

✓ **Work assist tooling** enables safe and efficient product handling across numerous industries in applications that require the movement of products, enhancing the efficiency of assembly and manufacturing operations

1.2.7.4 LEARNING ACTIVITIES

a) Practical Activity

Visit a site and identify various precautions observed by workers

1.2.7.5 Self-assessment test 7

Q1What is the purpose of environmental legislation?

Q2 what can the government's Health and Safety Inspection Service do when they see an offence?

Q 3 Which factor has a direct impact on the risks associated with work? C

Q 4 What is the objective of a task risk analysis?

Q 5 who should you notify right away about an accident?

1.2.7.6 Tools, Equipment, Supplies and Materials

a) Tools and equipment

- computer
- Hand tools
- Machine tools

b) Materials and supplies

- Computer software
- Construction materials
- Computers
- Stationery;
- Manufacturer's catalogues

c) Personal protective equipment (PPEs)

- Safety boots
- Goggles
- Gas masks
- Helmets
- Gloves
- Dust coats
- First aid kit
- Ear muffs
- Dust masks
- Overalls

1.2.7 Reference

Domone, P., & Illston, J. (Eds.). (2010). *Construction materials: their nature and behaviour*. CRC Press.

Chan, F. T. S., Ip, R. W. L., & Lau, H. (2001). Integration of expert system with analytic hierarchy process for the design of material handling equipment selection system. *Journal of Materials Processing Technology*, *116*(2-3), 137-145.

Johnston, J. E. (2016). *Site control of materials: Handling, storage and protection*. Elsevier.

Schaufelberger, J. E., & Migliaccio, G. C. (2019). *Construction equipment management*. Routledge**.**

Alumbugu, P. O., Shakantu, W. W., John, T. A., & Ola-Awo, A. W. AUTOMATION IN CONSTRUCTION MATERIALS HANDLING: THE CASE STUDY IN NORTH CENTRAL NIGERIA.

http://www.mnltap.umn.edu/topics/workplace/personal_protection_equipment/index.html

1.2.8 Responses to self-assessment test 7

Q1 **A**. To regulate the production of hazardous substances.
B To specify the methods that must be used for storing hazardous substances**.**
C To protect humans and the environment against hazardous substances

Q2 **A.** Impose a requirement and/or make a report of the offence.
B. Give the management a reprimand, suspend the work and withdraw the VCA (SCC) certificate.
C. Appoint an official to coordinate the work, give a warning and impose a requirement.

Q3 **A.** Impose a requirement and/or make a report of the offence.
B. Give the management a reprimand, suspend the work and withdraw the VCA (SCC) certificate.
C. Appoint an official to coordinate the work, give a warning and impose a requirement.

Q4 **A.** To control the risks associated with the work
B. To prepare for the proper execution of the work
C. To eliminate all risks

Q5 **A.** To control the risks associated with the work.
B. To prepare for the proper execution of the work.
C. To eliminate all risks