BASIC CIVIL ENGINEERING

UNIT I

Basics of Civil Engineering: Role of Civil Engineers in Society- Various Disciplines of Civil Engineering- Structural Engineering- Geo-technical Engineering- Transportation Engineering -Hydraulics and Water Resources Engineering - Environmental Engineering-Scope of each discipline - Building Construction and Planning- Construction Materials-Cement - Aggregate - Bricks- Cement concrete- Steel. Introduction to Prefabricated construction Techniques.

1. What is Civil Engineering?

• Civil ENGINEERING is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings.

2. Various contributions of Civil engineers to the welfare of the society:

1. Civil engineer will work on planning, design, construction and maintenance of projects such as roads, buildings, dams, bridges, sewages and water supply systems.
2. Civil engineering is about community service, development, and improvement.
3. Civil engineers often use theory and models to predict how a design will perform.
4. Civil engineers test their ideas on field without endangering life.
5. Civil engineers develop infrastructure for the society which is the backbone of the society.
6. Civil engineers increase the health and quality of life by developing better water supply, Sewage systems, and waste water plants, to protect from natural hazards and provide health care.
7. Civil engineers improve agriculture through water management systems and distribution projects.
8. Civil engineers provide solution for the rapid and dramatic changes of transportation.
9. Structural engineers deals with connections design, analysis and construction of components to resist loads from internal and external forces.
10. As a structural engineer, will face the challenge of analyzing and designing structures to ensure that they safely perform their purpose.
    - They must support their own weight and resist dynamic environmental loads such as hurricanes, earthquakes, blizzards, and floods.
    - Stadiums, arenas, skyscrapers, offshore oil structures, space platforms, amusement park rides, bridges, office buildings, and homes are a few of the many types of projects in which structural engineers are involved.
11. Structural engineers develop new materials other than steel and cements which withstand More loads & have high strength by weight ratio which includes FRP, polymers, etc,.
12. Geotechnical engineers apply the knowledge about the behavior of soils and its composition for design of foundations, retaining walls, earth dams, clay liners and geo-synthetics for waste condiments.
    - Examples of facilities in the earth are tunnels, deep foundations, and pipelines.
    - Highway pavements and many buildings are supported on the earth.

13. Certain important goals of geotechnical engineering include

1. Design of foundation
2.design temporary/permanent excavations
3.landfill disposal of waste.
4. Ground water contamination

14. Transportation plays and essential role in the development of the society by providing Trade routes and harbours air routes etc,.
15. Civil engineers plan, design, built, operate and maintain these of transport.
16. Civil engineers provide safe, efficient and convenient movement of people and goods
17. Civil engineers consider the forces and movements, weight and stress of the vehicles in motion and centrifugal forces at curves while the design the transportation.
18. The collection, storage, treatment, transmission and distribution of water played a significant role in urbanization, population growth and commercial agriculture and land use.
19. During the 20th century, water supply and distribution systems have led to an increase in life expectancy, reduction in infant mortality and morbidity, and improvements in environmental quality in developed countries.

3. ROLE OF CIVIL ENGINEERS:

- Main role of Civil engineers is in surveying, planning, designing, estimation and execution of structures.
- To solve different engineering problems with the help of field experience, laboratory techniques, numerical methods, mathematical models, using computer and information technology.
- To implement management techniques for better management of man, material, machine and money.
- To carry out soil investigation for design of foundations of structures.
- To invite tenders and to select contractor for the work.
- To carry out surveying and levelling and fixing the alignments (center-line) of roads, railways, canals, tunnels, pipes etc.
- To carry out planning of buildings as per its functional needs and also has role in town and regional planning.
- To carry out the design of structures as per the principles of structural analysis and design. Civil engineer should ensure that design is safe, durable and economic.
- To supervise the work during execution and to ensure progress of work.
- To carry out valuation of land or building for the purpose of finding its sale or purchase price or taxation.
- Civil engineers has to maintain public health by providing pure water for drinking, treating waste water before disposing in to water course and to collect the solid waste of town and disposing it.
- Civil engineer has to provide basic infrastructure of the structures for projects of many other engineering disciplines, like to design machine foundations and to provide steel frame structure and sheds for industries for the mechanical engineering project. To construct tunnels for hydropower station, to construction cooling tower for thermal power stations and to erect transmission towers for electrical lines for electrical engineering

4. Various Disciplines of Civil Engineering and their scope:

Structural Engineering
Geo-technical Engineering
Transportation Engineering
Hydraulics and Water Resources Engineering
Environmental Engineering

Structural Engineering:

- Constructing Residential buildings like apartments, tenements, flats, row houses, bungalows, villas, quarters etc.
- Constructing Public buildings like schools, colleges, government offices, post offices, hospitals, shopping complexes, hostels etc.
- Constructing Industrial buildings like workshops, ware houses, stores and industrial sheds.
- Constructing bridges, dams, ports, airports, underwater construction, tunnels, cofferdams, caissons, pile foundations etc. with Advanced Construction Techniques.
- It also includes study of several advanced techniques, modern equipment and materials.

Geo-technical Engineering:

- Constructing several types of foundations like simple footing, well foundation, pile foundation, cofferdams and foundations of machines subjected to vibrations is the main scope of geotechnical engineering.
- It further includes constructing tunnels, earthen dams, earth work for highways and railways. It also includes soil investigation and soil testing.

Transportation Engineering:

- Constructing structures related to the transportation engineering like roads, railways, bridges, tunnels, ports, harbours, runways and airports.
- It also includes traffic engineering and study of highway materials.
- Design, construction and maintenance of railway lines are part of transportation engineering.
- Globalization has resulted into requirement of airports and harbours.

Hydraulics and Water Resources Engineering:

- Water is an important need for all living beings. Study of mechanics of water and its flow characteristics is another important field in civil engineering and it is known as hydraulics.
- Rural areas need water for agricultural field also. Hence civil engineers have to look for new water resources and for storing them. This branch of civil engineering is known as water resources engineering.
- Water stored in reservoirs by building bunds and dams should be brought to agricultural fields through canals and distributaries. Study connected with this aspect is known as irrigation engineering

- Constructing structures relating to water resources engineering like dams, barrages, canals, canal structures and hydropower station. It also includes irrigation methods, water shed management, rain water harvesting, soil conservation, open channel hydraulics, flow measurement, hydrology, flood control and water power engineering.

Environmental Engineering:

- Constructing structures relating to public health engineering like units of water treatment plant (like intake, Clari-flocculator, rapid sand filter etc.), water distribution network, underground sump, overhead tank, units of wastewater treatment plant (like pumping well, screen chamber, grit chamber, primary settling tank, trickling filter, activated sludge unit, sludge unit, sludge digester, sludge drying beds etc.) sewerage and drainage system and pumping stations.
- It also includes pollution control and solid waste collection from the town and its disposal.

Construction Materials- Bricks:

- ✓ The common brick is one of the oldest building material and it is extensively used at present as a leading material of construction because of its durability, strength, reliability, low cost, easy availability, easy to handle etc..
- ✓ Bricks are used for building – up exterior and interior walls, partitions, piers, footings and other load bearing structures.
- ✓ The Great Wall of China (210 BC) was built with bricks. The other examples of the use of bricks in early stage of civilization could be in Rome. A number of country farm houses still exist in Great Britain and profess to be the monuments of the excellent hand – made bricks.
- ✓ A brick is rectangular in shape and of size that can be conveniently handled with one hand. Bricks may be made of burnt clay or mixture of sand and lime (or) of Portland cement concrete.
- ✓ Size of standard brick (also known as modular brick) should be 19 x 9 x 9 cm. However, the bricks available in most part of the country still are 9” x 4 ½” x 3” and are known as field bricks. Weight of such a brick is 3.0 kg.

COMPOSITION / INGREDIENTS OF GOOD BRICK EARTH:

For the preparation of bricks, clay is usually used. The clay used for brick making consists mainly of silica and alumina mixed in such a proportion that the clay becomes plastic when water is added to it. It also consists of small proportions of lime, iron, magnesium, sulphur etc.. The proportions of various ingredients and functions are as follows:

Silica 50 – 60 %
Alumina 20 – 30 %
Calcium 10 %; Mg < 1 %
Ferric Oxide < 7 % < 20 %
Alkalis < 10 % < 20 %
SO_3; H_2O < 2 % < 20 %

Silica: A good brick earth should contain about 50% to 60% of silica. The presence of silica constituent prevents cracking, shrinking in bricks thus imparts uniform shape to the bricks. Excess of silica makes the brick brittle and weak on burning. The durability of bricks depends on the proper proportion of silica in brick earth.
Alumina: A good brick earth should contain about 20 to 30% of alumina. If alumina is present in excess, with inadequate quantity of sand the raw bricks shrink and it produces cracks during drying and burning and become too hard when burnt.
Lime (calcium) : A small quantity of lime not exceeding 10% is desirable in good brick earth. The excess of lime causes the brick to melt and hence its shape is lost and also results in splitting of bricks into pieces.
Magnesia if exceeds 1%, affects the color and makes the brick yellow. Excess of magnesia content leads to the decay of bricks.
Iron – oxide usually constitutes < 7%. If it exceeds 7%, the brick becomes dark blue. When excess of oxygen is available, the bricks become dark brown or black color on burning.

MANUFACTURING OF BRICKS:

In the process of manufacturing of bricks, the following four distinct operations are involved:
1. Preparation of clay / Brick earth
2. Moulding
3. Drying
4. Burning

PREPARATION OF CLAY / BRICK EARTH consists of the following operations:
Un-soiling: The soil used for making building bricks should be processed and to be free from gravel, sand (> 2 mm) lime and kankar particles, organic matter etc. About 200 mm of the top layer of the earth, normally containing stones, pebbles, gravels, plant roots etc is removed after clearing the trees and vegetation.

Digging: The clay is then dug out from the ground and is spread on the ground. The height of heaps of clay on the ground is about 600 mm to 1200 mm. The digging operation should be done before rains.
weathering: The clay / soil is left in heaps and exposed to weather for at least one month. The soil should be turned over at least twice and it should be ensured that the entire soil is wet throughout the period of weathering. In order to keep it wet, water may be sprayed as often as necessary. The plasticity and strength of the clay are improved by exposing the clay to weather.

MOULDING: It is a process of giving a required shape to the brick from the prepared clay / soil / brick earth. Moulding may be carried out by hand or by machines.
Hand Moulding: In this process, the bricks are moulded by hand ie manually. It is adopted where man power is cheap and for producing a small quantity of bricks. A typical wooden mould should be prepared from well seasoned wood for making bricks.

The longer sides are kept slightly projecting to serve as handles. The strips of brass or steel are sometimes fixed on the edges of wooden moulds to make them more durable.

The steel mould even be prepared from steel angles and plates. The thickness of steel mould is generally 6 mm.

Machine Moulding: The moulding may also be achieved by machines. It proves to be economical when bricks in huge quantity are to be manufactured at the same spot in a short time.

Machine moulding can be done by either of the following process:

Plastic method (Plastic Clay Machine): The pugged clay is placed in the machine through a rectangular opening 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 and this is a quick and economical process. This process is also known as WIRE CUT BRICKS.

Dry Press Method / Dry Clay Method: In these machines, the strong clay is first converted into powder from. A small quantity of water is 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 also known as PRESSED BRICKS. They can be sent directly for the next process of burning.

DRYING: For drying, the bricks are laid longitudinally in stacks of width equal to two bricks. A stack consist of 8 or 10 tiers or courses. The bricks are laid along and across the stack in alternate layers. All bricks are placed on edge. The bricks in stakes should be arranged in such a way that sufficient air space is left between them. The bricks should be allowed to dry till they become hard or the moisture content is brought down to about 3% under exposed conditions within 3 to 4 days. For the drying purpose, Drying yards should be prepared. The Drying yards should be slightly on a higher level and it is desirable to cover it with sand. Such an arrangement would prevent the accumulation of rain water.

BURNING: This is a very important operation in the manufacture of bricks. The burning of clay may be divided into three main stages.

Dehydration stage (400 – 650^0 C): This is also known as water smoking stage.
During dehydration :

- ✓ The water which has been retained in the pores of the clay after drying is driven off;
- ✓ Some of the carbonaceous matter is burnt;
- ✓ Carbonated minerals are more or less decarbonated;
- ✓ Too rapid heating causes cracking or bursting of the bricks.

Oxidation period (650–900^{0}C): During the oxidation period, the remaining carbon is eliminated and the ferrous iron is oxidized to the ferric form.
Removal of sulphur is completed only after the carbon has been eliminated.

Types of Tests on Bricks for Construction Purpose:

Following tests are conducted on bricks to determine its suitability for construction work.

- Absorption test
- Crushing strength test
- Hardness test
- Shape and size
- Color test
- Soundness test
- Structure of brick

1. Absorption Test on Bricks:
Absorption test is conducted on brick to find out the amount of moisture content absorbed by brick under extreme conditions. In this test, sample dry bricks are taken and weighed. After weighing these bricks are placed in water with full immersing for a period of 24 hours. Then weigh the wet brick and note down its value. The difference between dry and wet brick weights will give the amount of water absorption. For a good quality brick the amount of water absorption should not exceed 20% of weight of dry brick.

2. Crushing Strength or Compressive Strength Test on Bricks:
Crushing strength of bricks is determined by placing brick in compression testing machine. After placing the brick in compression testing machine, apply load on it until brick breaks. Note down the value of failure load and find out the crushing strength value of brick. Minimum crushing strength of brick is 3.50N/mm^2.if it is less than 3.50 N/mm^2, then it is not useful for construction purpose.

3. Hardness Test on Bricks:
A good brick should resist scratches against sharp things. So, for this test a sharp tool or finger nail is used to make scratch on brick. If there is no scratch impression on brick then it is said to be hard brick.

4. Shape and Size Test on Bricks:
Shape and size of bricks are very important consideration. All bricks used for construction should be of same size. The shape of bricks should be purely rectangular with sharp edges. Standard brick size consists length x breadth x height as 19 cm x 9 cm x 9 cm. To perform this test, select 20 bricks randomly from brick group and stack them along its length , breadth and height and compare. So, if all bricks similar size then they are qualified for construction work.

5. Colour Test of Bricks:
A good brick should possess bright and uniform colors throughout its body.

6. Soundness Test of Bricks:
Soundness test of bricks shows the nature of bricks against sudden impact. In this test, 2 bricks are chosen randomly and struck with one another. Then sound produced should be clear bell ringing sound and brick should not break. Then it is said to be good brick.

7. Structure of Bricks:
To know the structure of brick, pick one brick randomly from the group and break it. Observe the inner portion of brick clearly. It should be free from lumps and homogeneous.

Construction Materials- Cement:

- The natural cement is obtained by burning and crushing the stones containing clay, carbonate of lime ($CaCO_3$) and a little quantity of magnesia. The natural cement is brown in color and is also known as Roman cement.
- The artificial cement was invented by a mason Joseph Aspedin in England in 1824. He took out a patent for this cement and called it Portland cement because it had resemblance in its color after setting, to a variety of sandstone which is found in Portland in England.

Raw Materials of Portland cement:

1- Calcareous rocks (such as limestone, marl, chalk)

2- Argillaceous rocks (such as clay and shale),

Materials from any two of these groups may be used for Portland cement production providing that they must contain, in proper form and proportions of lime, silica and alumina.

Types of Cement in India as per Hardening and Setting Mechanism

Hydraulic and non-hydraulic are the two categories of cement according to the hardening and setting mechanism.

Hydraulic Cement:
This type of cement refers to the materials that get hardened via the hydration process in the presence of water. For making this type of cement, raw materials, such as clay, limestone and gypsum, are used. The raw material must be burned at a high temperature to form hydraulic cement.

The process of making Hydraulic cement involves grinding clinkers that are primarily made of hydraulic calcium silicates. Calcium sulfate in one or more forms as an inter-ground addition exists in the process. Hydraulic cement gets hardened through a reaction with water and develops a water-resistant product.

Non-Hydraulic Cement:

Non-Hydraulic Cement does not necessarily require water for hardening. It gets hardened via the reaction of carbonation with naturally occurring carbon dioxide in the air. Dry conditions are mandatory for this type of cement to get hardened. Non-hydraulic cement is formed through raw materials, such as lime, oxychloride and gypsum plasters. An example of a non-hydraulic cement is Slaked lime. Non-hydraulic cement is rarely used these days because it takes a long time to set.

PROPERTIES OF CEMENT:

- It gives strength to the masonry works.
- It is an excellent binding material.
- It is easily workable
- It offers good resistance to the moisture
- It possesses a good plasticity.
- It hardens early.

COMPOSITION OF ORDINARY CEMENT/ PORTLAND CEMENT:

Compound	Percentage %
CaO	63
SiO_2	20
Al_2O_3	6
Fe_2O_3	3
SO_3	2
MgO	1.5
$Na_2O+ K_2O$	1
Miscellaneous	3.5

CaO – controls strength and soundness. Its deficiency reduces strength and setting time.

SiO_2 - gives strength. Excess of it causes slow setting.

Al_2O_3- responsible for quick setting, if in excess, it lowers the strength.

Fe_2O_3- gives colour and helps in fusion of different ingredients.

MgO- imparts colour and hardness. If in excess, it causes cracks in mortar and concrete and unsoundness.

$Na_2O+ K_2O$ - these are residues, and if in excess cause efflorescence and cracking.

ORDINARY PORTLAND CEMENT:

- The artificial cement is obtained by burning at a very high temperature of a mixture of calcareous (lime stone) and argillaceous (clay) materials. The calcined product is known as the CLINKER.
- A small quantity of gypsum is added to the clinker and it is then pulverized into very fine powder which is known as the CEMENT. This cement is also known as the normal setting cement or ordinary cement.
- **The Ordinary Portland Cement has been classified as 33 Grade (IS269: 1989); 43 Grade (IS 8112:1989) and 53 Grade (IS 12669:1987).**

TYPES OF CEMENTS:

- ✓ Ordinary Portland Cement (OPC) IS 269:1989, , IS 8112:1989, IS 12269:1987
- ✓ Rapid Hardening Cement (RHC) IS 8041:1990
- ✓ Sulphate Resisting Cement IS 12330:1988
- ✓ Portland Slag Cement IS 455:1989
- ✓ Quick Setting Cement
- ✓ White Cement IS 8042:1989
- ✓ Hydrophobic Cement IS 8043:1991

Ordinary Portland Cement Uses:

- It is used for general construction purposes
- It is also used in most of the masonry works

Rapid Hardening Cement Uses:

- In prefabricated constructions.
- Where formwork is required to be removed early for re-use elsewhere.
- Road repair works
- In cold weather concrete, where the rapid rate of development of strength reduces the vulnerability of concrete to the frost damage.

Sulphate Resisting Cement:

Sulphate attack is greatly accelerated if accompanied by alternate wetting and drying which normally takes place in marine structures in the zone of tidal variations.

USES:

- Concrete to be used in marine condition.
- Concrete to be used in foundation and basement, where soil is infested with sulphates.
- Concrete to be used in the construction of sewage treatment works.
- Concrete used for fabrication of pipes which are likely to be buried in marshy region or sulphate bearing soils.

Portland Slag Cement:

OPC clinker + 25-60% granulated blast-furnace slag. Granulated blast-furnace slag is a waste product of the manufacture of iron. The amount of iron and slag being obtained is in the same order. A proper slag is a mixture of;
Lime = 40% , Silica = 30% , Alumina = 20%, Magnesia = 5%, Alkali Oxides = 1%

This cement is less reactive than OPC and gains strength at a slower rate during first 28 days, so adequate curing is essential.

Uses:

- ✓ suitable for mass concrete
- ✓ unsuitable for cold weather
- ✓ has high sulfate resistance (suitable for use in sea-water construction).

Quick Setting Cement:

- Quick setting cement is the cement which sets in a very short time.
- The initial setting time is 5 minutes and the final setting time is 30 minutes.
- The composition of Quick Setting Cement:
    - Clinker
    - Aluminium sulphate (1% to 3% by weight of clinker)
- The aluminium sulphate increase the hydration rate of silicate.

Uses of Quick Setting Cement:

- It is used in underwater Construction.
- It is also used in rainy & cold weather conditions.
- It is used a higher temperature where water evaporates easily.
- Used for anchoring or rock bolt mining and tunnelling

White Cement:

- It is made from raw materials containing very little iron oxide and manganese oxide. China clay (Kaolin) is generally used together with chalk or limestone free from specified impurities (iron oxide, manganese oxide).
- The cost of grinding is higher and this completed with the more expensive raw materials makes White Cement rather expensive (about 2 times).
- WPC is used for architectural purposes. It is not liable to cause staining, since it has a low content of soluble alkalies.

Uses of White Cement:

- ✓ It is usually used in decorative work.
- ✓ It can also use for traffic barriers, tile grouts, swimming pools, roof tiles patching materials and terrazzo surfaces.

Hydrophobic Cement:

- ✓ Hydrophobic cement is obtained by grinding ordinary Portland cement clinker with water repellent film-forming substance such as oleic acid, and stearic acid.
- ✓ The water-repellent film formed around each grain of cement, reduces the rate of deterioration of the cement during long storage, transport, or under unfavourable conditions.
- ✓ The film is broken out when the cement and aggregate are mixed together at the mixer exposing the cement particles for normal hydration.
- ✓ The film forming water-repellent material will entrain certain amount of air in the body of the concrete which incidentally will improve the workability of concrete.
- ✓ Ordinary cement gets deteriorated and loses some if its strength, whereas the hydrophobic cement which does not lose strength is an answer for such situations.

Uses of Hydrophobic Cement:

- Usually, it is used in the construction of water structures such as dams, spillways, or other submerged structures.
- It is also used in the construction of underground structure like tunnel etc.

Testing of Cement:

1. Field Testing
2. Laboratory Testing

Field Testing:

- Open the bag and take a good look at the cement. There should not be any visible lumps.
- The Colour of the cement should normally be greenish grey.
- Thrust your hand into the cement bag. It must give you a cool feeling. There should not be any lump inside.
- Take a pinch of cement and feel between the fingers. It should give a smooth and not a gritty feeling.
- Take a handful of cement and throw it on a bucket full of water, the particles should float for some time before they sink.

Chemical or Laboratory Tests:

- ✓ Fineness Test
- ✓ Normal Consistency, Initial Setting time and Final Setting time Tests
- ✓ Strength Test
- ✓ Soundness Test

Fineness Test:

- The fineness of cement is a measure of the size of particles of the cement. It is expressed in the term of specific surface area (cm2/g).
- It is an important factor in determining the rate of gain of strength and uniformity in quality.
- The finer the cement greater is the surface area for the chemical reaction and thus greater is the rate of hydration and also is the greater heat of the hydration. This results in the early development of strength.

Fineness Test-Sieve test [IS: 4031 (Part 1)]

- It is not a modern test.
- In this cement is passed through 90-micron sieve and the residue left on the sieve should not be more than 10 percent.

Normal Consistency, Initial Setting time and Final Setting time Tests:

- ✓ The term consistency is used to indicate the ability of cement paste to deform with the change in water content.
- ✓ But consistency test is carried out as it is used as an indicator test for several tests like setting time and soundness.
- ✓ The consistency test is used to determine the water required for testing Initial Setting Time and Final Setting Time tests.

Setting Time [IS: 4031 (Part 5)]

Setting time is used to find the extent of deterioration caused due to storage of cement.

Initial setting time

Initial setting time is defined as the time which is measured from the instant at which water is added to cement and at the time at which cement starts losing its plasticity.

Final setting time:
It is the time taken from the instant of adding water to the time at which cement becomes sufficiently stiff to lose all of its plasticity and resists definite pressure.

Types of cement	Initial setting time	Final setting time
OPC (all grades)	30 minutes	600 minutes
Rapid Hardening Cement	5 minutes	30 minutes
Low heat cement	60 minutes	600 minutes

Soundness [IS: 4031 (Part 2)]

Due to some of the constituents of raw materials of cement like lime (CaO), magnesia (MgO) and sulphur (mainly in form of SO3) cement may undergo undesirable expansion after getting set and this may lead to the cracking and disintegration of concrete and thus causing brittle failure of concrete.

Strength Tests:

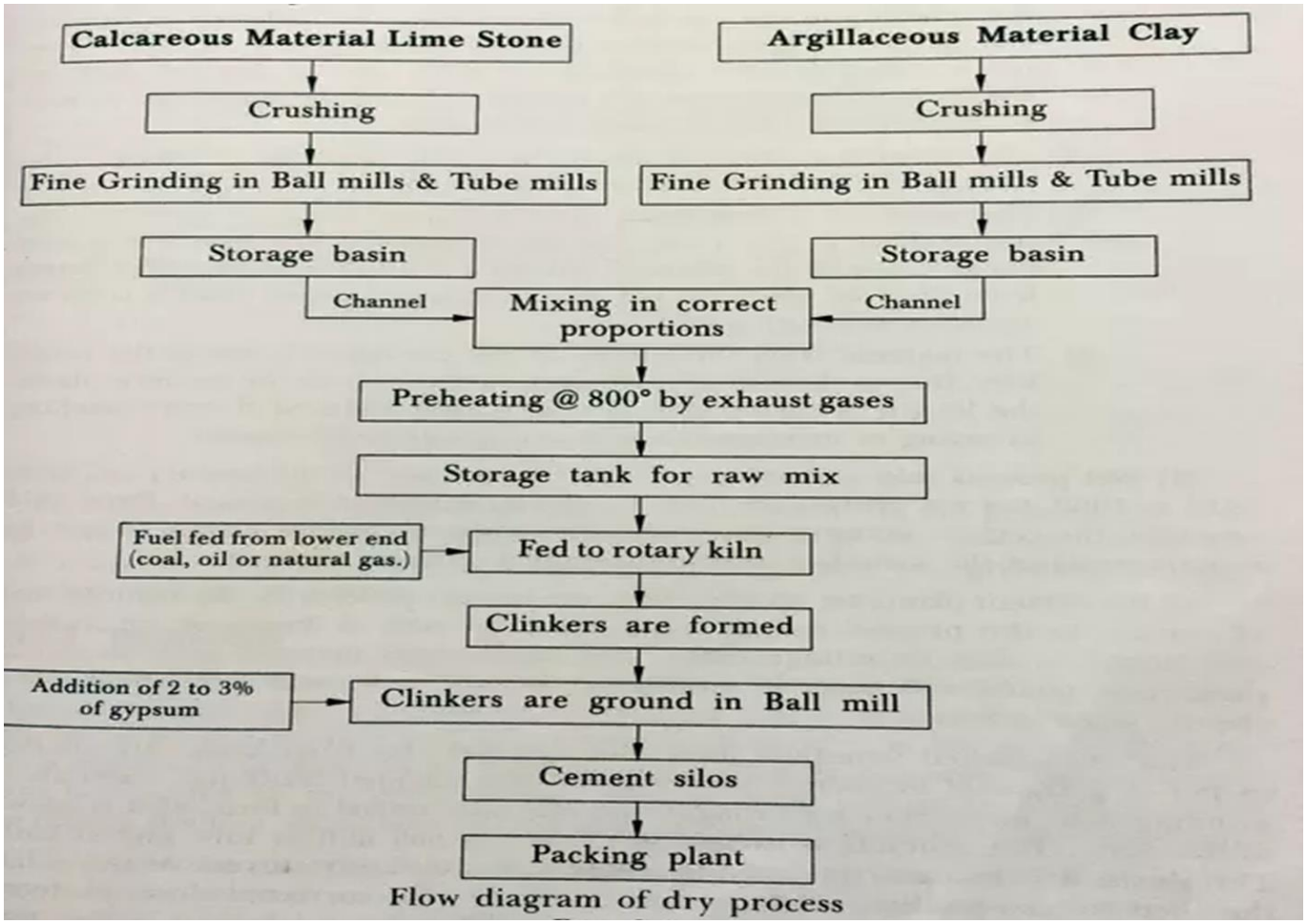
- The strength of mortar and concrete depends upon the type and nature of cement.
- So, it should develop a minimum specified strength if it is to be used in structures.
- Cement is tested for compressive and tensile strengths.

Compressive strength:

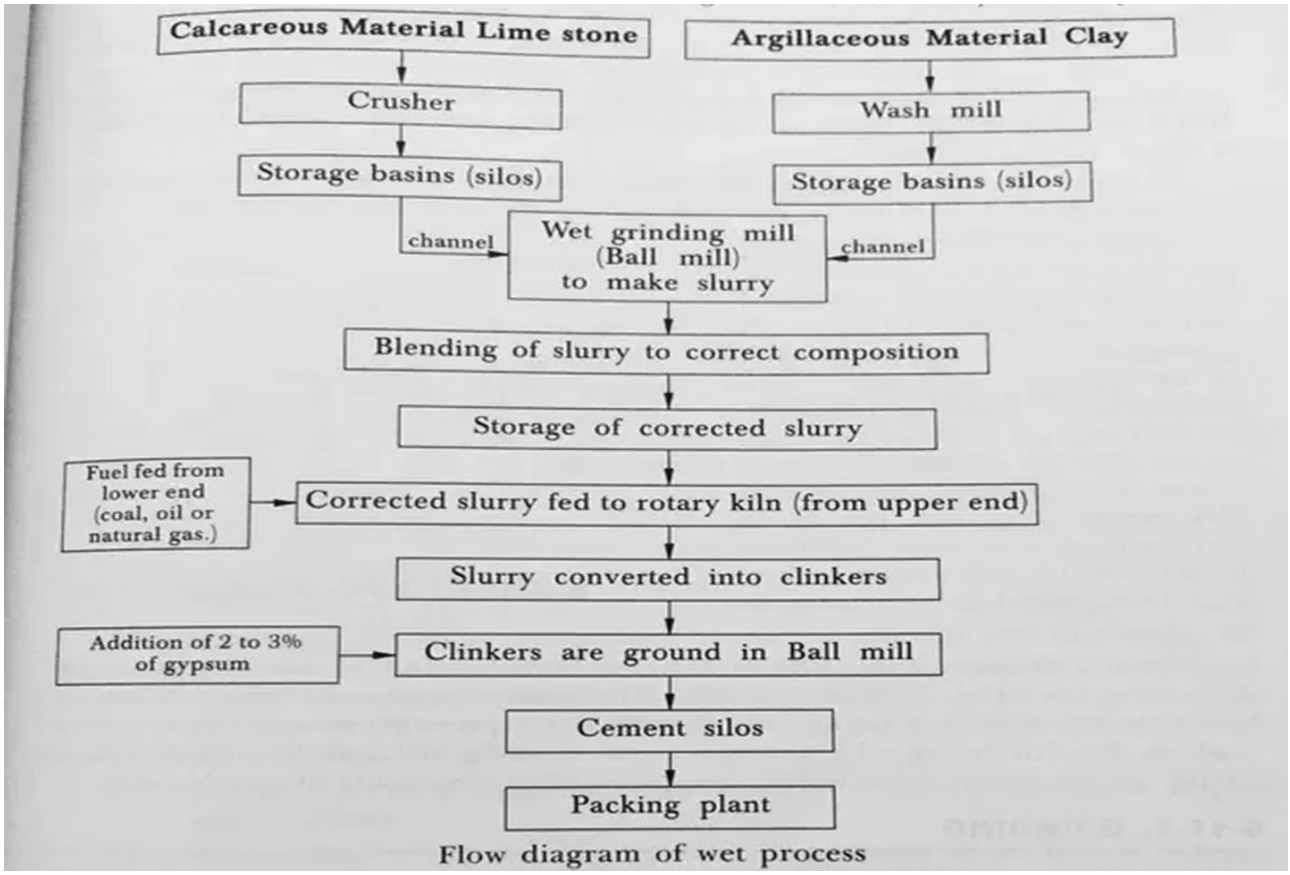
- ✓ Compressive strength is the basic data required for mix design.
- ✓ By this test, the quality and the quantity of concrete can be controlled and the degree of adulteration can be checked.
- ✓ The test specimens are 70.6 mm cubes having face area of about 5000 sq. mm. Large size specimen cubes cannot be made since cement shrinks and cracks may develop.
- ✓ Three specimen cubes are prepared.
- ✓ The cubes are then removed from the moulds and submerged in clean fresh water and are taken out just prior to testing in a compression testing machine.
- ✓ Compressive strength is taken to be the average of the results of the three cubes.
- ✓ The load is applied starting from zero at a rate of 35 N/sq mm/minute.
- ✓ The compressive strength is calculated from the crushing load divided by the average area over which the load is applied.
- ✓ The result is expressed in N/mm^2.

Methods of Manufacturing of cement:

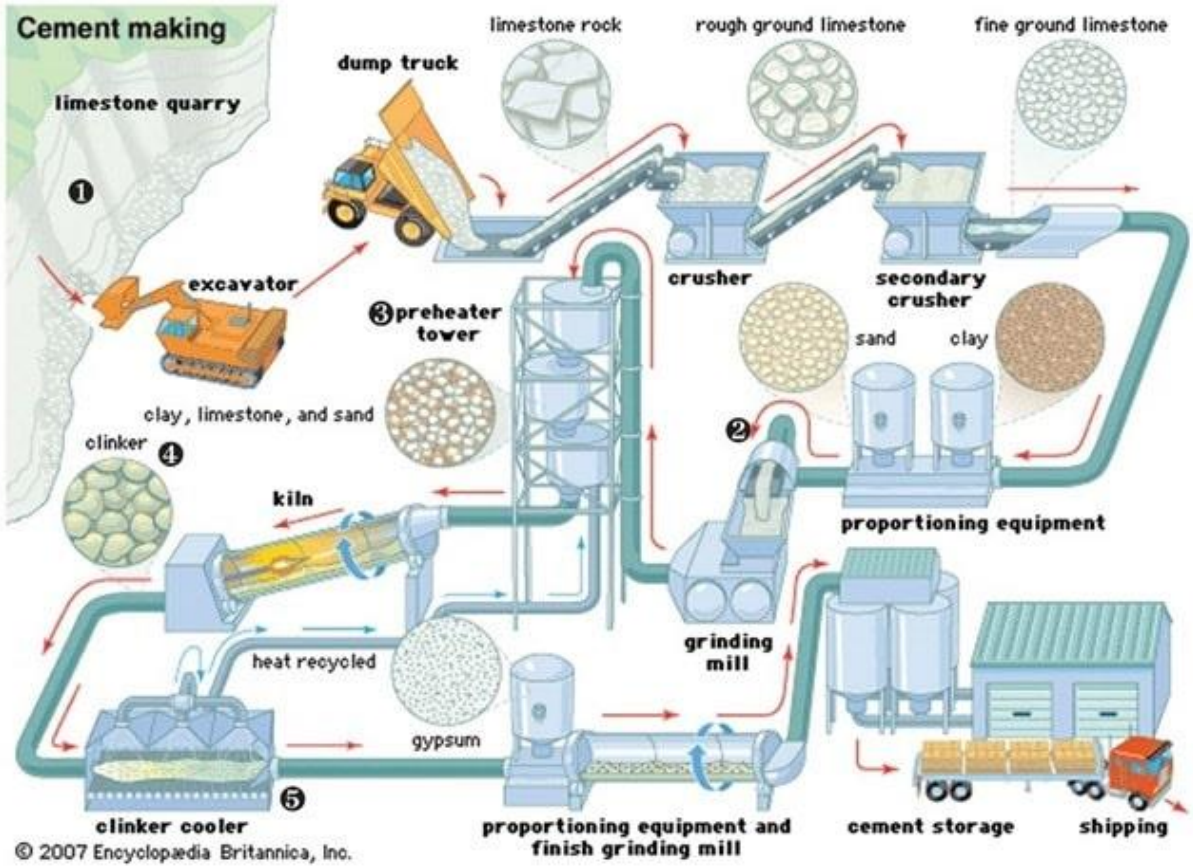
1. Dry process and
2. wet process



Flow diagram of dry process



Flow diagram of wet process



Construction Materials – Aggregate:

Aggregate:

It is defined as: "Aggregates are the inert materials that are mixed in fixed proportions with a Binding Material to produce concrete".

These act as fillers or volume increasing components on the one hand and are responsible for the strength, hardness, and durability of the concrete on the other hand.

Aggregate Origin and Geology:

Aggregates are commonly obtained by crushing naturally occurring rock. The properties of aggregates depend on the parent rock which can be igneous, sedimentary, or metamorphic. Aggregates are evaluated through tests to determine their suitability for various applications. Mineralogy, grain size and texture, and petrographic description of rock samples are also used to evaluate suitability.

Aggregate Classification or Types of Aggregates:

Aggregates are variously classified on the basis of their grain size, their origin, and their volume-weight as follows:

(1.) Aggregate Types on the basis of Grain Size.

This is the most common classification; where in two types of aggregates are distinguished: (Fine and Coarse).

(i) Fine Aggregates.

- In the Fine Aggregates, the grain-size lies between 4.75 mm and 0.15 mm.
- In other words, this pass-through from sieve with the mesh size of 4.75 mm and are retained on a sieve of 0.15 mesh size.
- Sand is the most universally available natural Fine Aggregate

(ii) Coarse Aggregates:

- Coarse aggregates are those that are retained on the sieve of mesh size 4.75 mm.
- Their upper size is generally around 7.5 mm.
- Gravels from river bed are the best coarse aggregates in the making of Common Concrete.
- In those situations, if they are not easily available, Suitable rock types are crushed to the desired particle sizes for making coarse aggregates.

(2.) Types on the Basis of origin.

There are three types on the Basis of Origin.

(i) Natural:

These include all those types of fine and coarse aggregates, that are available in almost ready to use form, from natural resources.

Examples are sands from river beds, pits and beaches, and gravels from river banks.

(ii) Bye-product:

These include materials obtained as wastes from some industrial and metallurgical engineering operations, which possess suitable properties for being used as aggregate.

Examples: Cinder obtained from burning of coal in locomotives and kilns.

And Slag is obtained from blast furnaces as Scum is the best example from this category.

(iii) Processed:

These form a special class in Aggregate. They are specifically manufactured for use in making Quality Concretes.

Examples: They include burnt clay, Shales, vermiculite's and perlite. They are essential Ingredients of Lightweight Concrete.

(3.) Types on the Basis of Density.

Three types of aggregates are distinguished on the basis of their weight per unit volume.

(i) Standard or Normal:

These types of aggregates give strength and weighting to the Concrete of around 2300 to 2500 kg/m^3.

Gravels, Sand and Crushed stone, are all classed as Standard or Normal Aggregates.

(ii) High-Density Aggregates:

These are that type of Aggregates, which is used in standard proportions yield in heavy weight concretes. Such concretes are especially useful as shields against X-rays and radiations in the atomic power plant.

Examples: Baryle – a natural mineral with a specific gravity of 4.3 is an example.

Concretes with such aggregate usually weight above 4000 kg/m^3.

(iii) Light weight Aggregate:

They consist of natural and artificial materials of very low density so that the resulting concrete is also quite Light in weight, generally with in a range of 350 to 750 kg/m^3.

They are specially used in sound proofing and fire proofing constructions.

They are also used extensively in the manufacture of light weight Pre-Cast concrete.

PREFABRICATED STRUCTURES & PREFABRICATION – CONCEPT & COMPONENTS:

Concept of prefabrication:

Prefabrication is the method of construction which includes assembling components of a structure in a manufacturing or production site, transporting complete assemblies or partial assemblies to the site where the structure is to be located. It is combination of good design with modern high performance components and quality controlled manufacturing procedures. This work is carried out in two stages, manufacturing of components in a place other than final location and their erection in position.

Prefabricated sections are produced in large quantities in a factory and then shipped to various construction sites. This procedure may allow work to continue despite poor weather conditions and should reduce any waste in time and material at the site. Precast concrete units are cast and hardened before being used for construction. Sometimes builders cast components at the building site and hoist them into place after they harden. This technique permits the speedy erection of structures.

Pre Fabrication

The Prefabrication as defined will be done in two stages

1. Manufacturing at factory condition and erection of
2. Components at the required location.

This requires certain stages of preparation. They are Casting, Curing, Transportation and erection.

Casting: – Precast components are casted with controlled cement concrete in moulds of required shape and sizes. The vibrator is used to vibrate concrete and this removes any honeycombing inside the components.

Curing: – After 24 hours of casting, the casted components are released from the mould and transported to curing tanks. Certain special components like railway sleepers where high strength is required are steam cured.

Transportation and erection: – After complete curing is done the components are transported to the site with heavy trucks and erection will be done using cranes with skilled labour force.

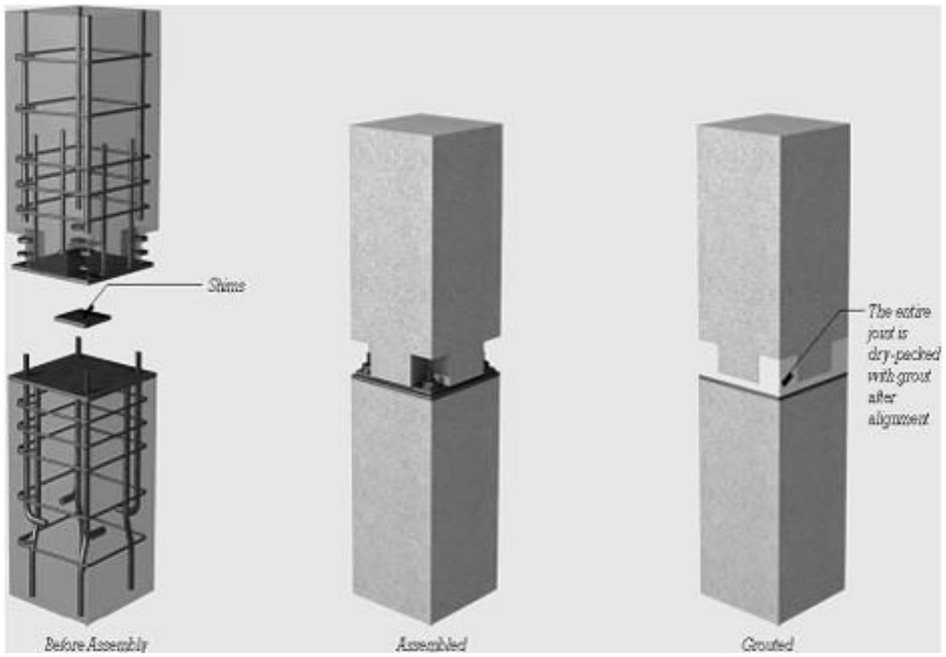
casted with controlled cement concrete in moulds

Prefab Building Components:

Some of the prefabricated components are as explained below

Columns: – A column is a vertical member carrying the beam and floor loadings to the foundation. It is a compression member and therefore the column connection is required to be proper. The main principle involved in making column connections is to ensure continuity and this can be achieved by a variety of methods.

Beams: – Beams can vary in their complexity of design and reinforcement from the very simple beam formed over an isolated opening to the more common encountered in frames where the beams transfer their loadings to the column.

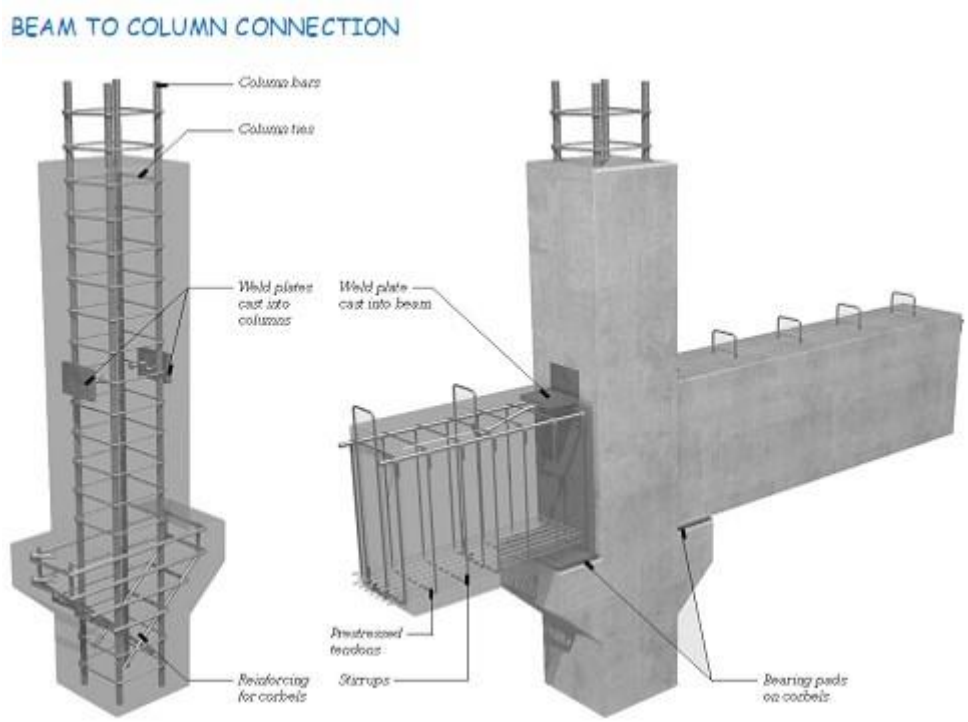


Prefab Column to Column Connection

Methods of connecting beams and columns are

- A precasting concrete haunch is cast on to the column with a locating dowel or stud bolt to fix the beam.
- A projecting metal corbel is fixed to the column and the beam is bolted to the corbel.
- Column and beam reinforcement, generally in the form of hooks, are left exposed. The two members are hooked together and covered with insitu concrete to complete the joint.

Waffle unit for flooring / roofing: – These are suitable for roofs / floors spanning in two directions. They are laid in a grid pattern. These units are cast in moulds. The saving achieved is not much. Also Shuttering are complicated and costly. Time consumption for construction is less.



Prefab Column to Beam Connection

Advantages and Disadvantages:

Advantages:

- ✓ Saving in cost, material, time & manpower.
- ✓ Shuttering and scaffolding is not necessary.
- ✓ Installation of building services and finishes can be done immediately.
- ✓ Independent of weather condition.
- ✓ Components produced at close supervision .so quality is good
- ✓ Clean and dry work at site.
- ✓ Possibility of alterations and reuse
- ✓ Correct shape and dimensions and sharp edges are maintained.
- ✓ Very thin sections can be entirely precast with precision.

Disadvantages:

- ✓ Handling and transportation may cause breakages of members during the transit and extra provision is to be made.
- ✓ Difficulty in connecting precast units so as to produce same effect as monolithic. This leads to non-monolithic construction.
- ✓ They are to be exactly placed in position, otherwise the loads coming on them are likely to get changed and the member may be affected.
- ✓ Disadvantages:
- ✓ High transport cost
- ✓ Need of erection equipment
- ✓ Skilled labour and supervision is required.

BUILDING CONSTRUCTION:

Foundations:

Foundation is one of the essential parts of the structure. It is defined as that part of the structure that transfers the load from the structure constructed on it as well as its weight over a large area of soil in such a way that the amount does not exceed the ultimate bearing capacity of the soil and the settlement of the whole structure remains within a tolerable limit. Foundation is the part of a structure on which the building stands. The solid ground on which it rests is known as the foundation bed.

Why a Foundation is Provided

Foundation should fulfil the following objectives:

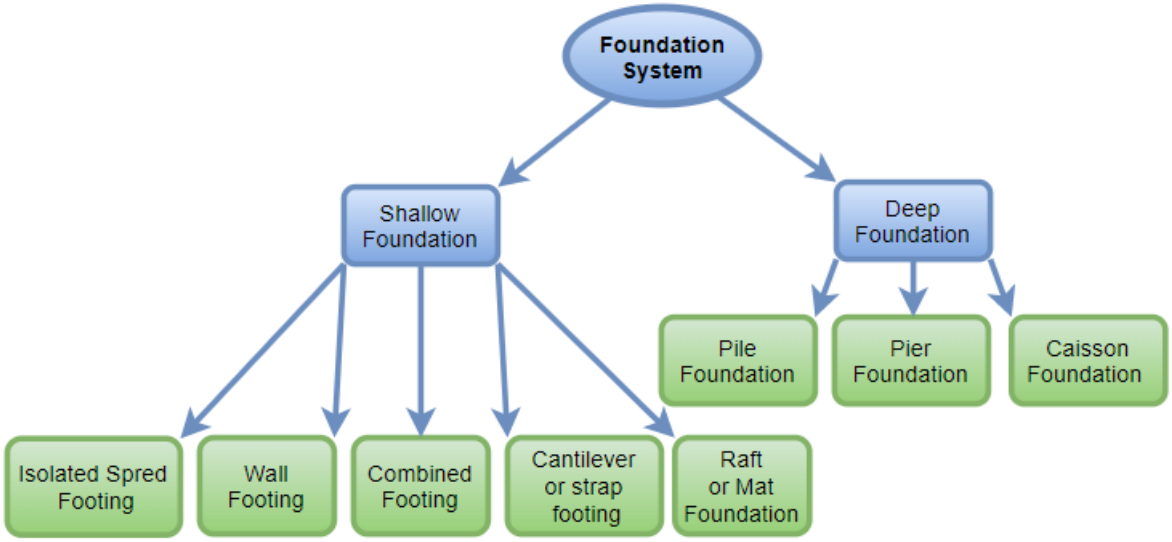
- ➢ Distribute the weight of the structure over a large area of soil.
- ➢ Avoid unequal settlement.
- ➢ Prevent the lateral movement of the structure.
- ➢ Increase structural stability.

Why there are Different Types of Footing

As we know that there are different types of soil, and the bearing capacity of the soil is different for each type of soil. Depending on the soil profile, size, and load of the structure, engineers chose different kinds of foundations.

Types of Foundation

In general, all foundations are divided into two categories, - **shallow and deep foundations**. The terms Shallow and Deep Foundation refer to the depth of the soil at which it is placed. Generally, if the **width of the foundation is greater than the depth, it is labelled as the "Shallow Foundation". If the width is smaller than the depth of the foundation it is called a "Deep Foundation."** However, deep foundation and shallow foundation can be classified as shown in the following chart.



Types of Shallow Foundation

The followings are the types of shallow foundations.

1. Isolated Spread Footing

This is the most widely recognized and most straightforward shallow foundation type, as this is the most economical type. They are typically utilized for shallow establishments to convey and spread concentrated burdens caused, for instance, by pillars or columns. They are generally used for ordinary buildings (Typically up to five stories).

Figure: Isolated shallow foundation image

Isolated footing comprises a foundation directly at the base of the segment. Generally, every section has its footing. They straightforwardly transfer the loads from the column to the soil. It might be rectangular, square, or roundabout. It can comprise both reinforced and non-reinforced material. For the non-reinforced footing, however, the stature of the footing has to be more prominent to give the vital spreading of the load. They should possibly be utilized when it is sure beyond a shadow of a doubt that no differing settlements will happen under the whole structure. Spread footings are inadmissible for the orientation of large loads. It is given to lessen the twisting minutes and shearing powers in their primary areas.

The size of the footing can be roughly calculated by dividing the total load at the column base by the allowable bearing capacity of the soil.

The followings are the types of spread footing.

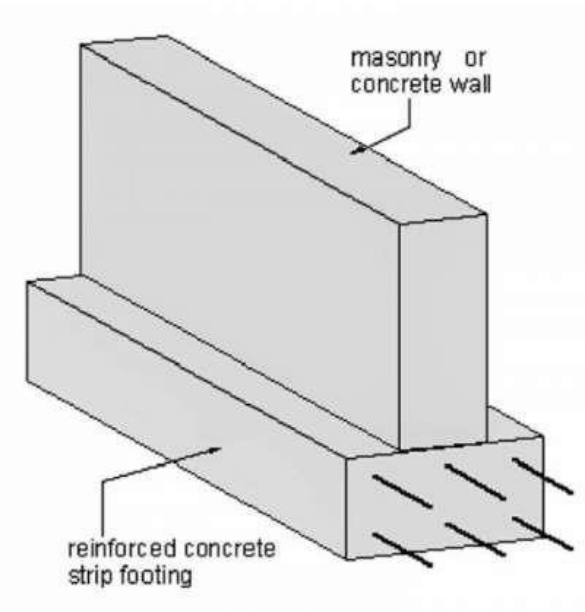
1. Single pad footing.
2. Stepped footing for a column.
3. Sloped footing for a column.
4. Wall footing without step.
5. Stepped footing for walls.
6. Grillage foundation.

To decide when to use shallow foundations, it is necessary to know when it is economical. It is economical when:

- The load of the structure is relatively low.
- Columns are not closely placed.
- The bearing capacity of the soil is high at a shallow depth.

2. Wall Footing or Strip footing

Wall footing is also known as continuous footing. This type is used to distribute loads of structural or non-structural load-bearing walls to the ground in such a way that the load-bearing limit of the soil isn't outperformed. It runs along the direction of the wall. The width of the wall foundation is usually 2-3 times the width of the wall.



The wall footing is a continuous slab strip along the length of the wall. Stone, brick, reinforced concrete, etc. are used for the construction of wall foundations.

- On account of block walls, the footing comprises a few courses of bricks, the least course being generally double the expansiveness of the wall above.
- On account of stone masonry walls, the counterbalances could be 15 cm, with the statues of the course as 30 cm. Along these lines, the size of the footings is marginally more than that of the block divider footings.
- If the heap on the wall is substantial or the soil is of low bearing limit, this reinforced concrete foundation type can be given.

Wall footing is economical when:

- ✓ Loads to be transmitted are of small magnitude.
- ✓ It is placed on dense sand and gravel.

3. Combined Footing

The combined footing is very similar to the isolated footing. When the columns of the structure are carefully placed, or the bearing capacity of the soil is low and their footing overlaps each other, combined footing is provided. It is fundamentally a blend of different footings, which uses the properties of various balances in a single footing dependent on the necessity of the structure.

The foundations which are made common to more than one column are called combined footings. There are different types of combined footing, including slab type, slab and beam type, and rectangular, raft, and strap beam type. They may be square, tee-shaped, or trapezoidal. The main objective is the uniform distribution of loads under the entire area of footing, for this is necessary to coincide with the center of gravity of the footing area with the center of gravity of the total loads.

Combined foundations are economic when:

- ✓ The columns are placed close to each other.
- ✓ When the column is close to the property line and the isolated footing would cross the property line or become eccentric.
- ✓ Dimensions of one side of the footing are restricted to some lower value.

5. Raft or Mat Foundation

Raft or Mat foundations are used where other shallow or pile foundations are not suitable. It is also recommended in situations where the bearing capacity of the soil is inadequate, the load of the structure is to be distributed over a large area, or the structure is subjected continuously to shocks or jerks.

A raft foundation consists of a reinforced concrete slab or T-beam slab placed over the entire area of the structure. In this type, the whole basement floor slab acts as the foundation. The total load of the structure is spread evenly over the entire area of the structure. This is called a raft because, in this case, the building seems like a vessel that floats on a sea of soil.

Raft foundations are economic when:

- ✓ The soil is weak and the load has to be spread over a large area.
- ✓ The structure includes a basement.
- ✓ Columns are closely placed.
- ✓ Other kinds of foundations are not feasible.
- ✓ Differential settlement is to be prevented.

Figure: Raft or Mat foundations

Deep Foundations

Several Types of Deep Foundations Are Discussed Below.

Types of Deep Foundation.

The followings are the types of deep foundations.

1. Pile Foundation

Pile is a common type of deep foundation. They are used to reduce cost, and when as per soil condition considerations, it is desirable to transmit loads to soil strata that are beyond the reach of shallow foundations.

The followings are the types of pile foundations.

Based on Function or Use

1. Sheet Piles
2. Load Bearing Piles
3. End Bearing Piles
4. Friction Piles
5. Soil Compactor Piles

Based on Materials and Construction Method

1. Timber Piles
2. Concrete Piles
3. Steel Piles
4. Composite Piles

Pile is a slender member with a small cross-sectional area compared to its length. It is used to transmit foundation loads to deeper soil or rock strata when the bearing capacity of soil near the surface is relatively low. Pile transmits load either by skin friction or bearing. Piles are also used to resist structures against uplift and provide structures stability against lateral and overturning forces.

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Pile foundations are economic when

- ✓ Soil with great bearing capacity is at a greater depth.
- ✓ When there are chances of construction of irrigation canals in the nearby area.
- ✓ When it is very expensive to provide raft or grillage.
- ✓ When the foundation is subjected to a heavily concentrated load.
- ✓ In marshy places.
- ✓ When the topsoil layer is compressible in nature.
- ✓ In the case of bridges, when the scouring is more in the river bed.

2. Pier Foundation

Pier is an underground structure that transmits a more massive load, which cannot be carried by shallow foundations. It is usually shallower than piles. The pier foundation is generally utilized in multi-story structures. Since the base region is determined by the plan strategy for the regular establishment, the single pier load test is wiped out. Along these lines, it is increasingly well-known under tight conditions.

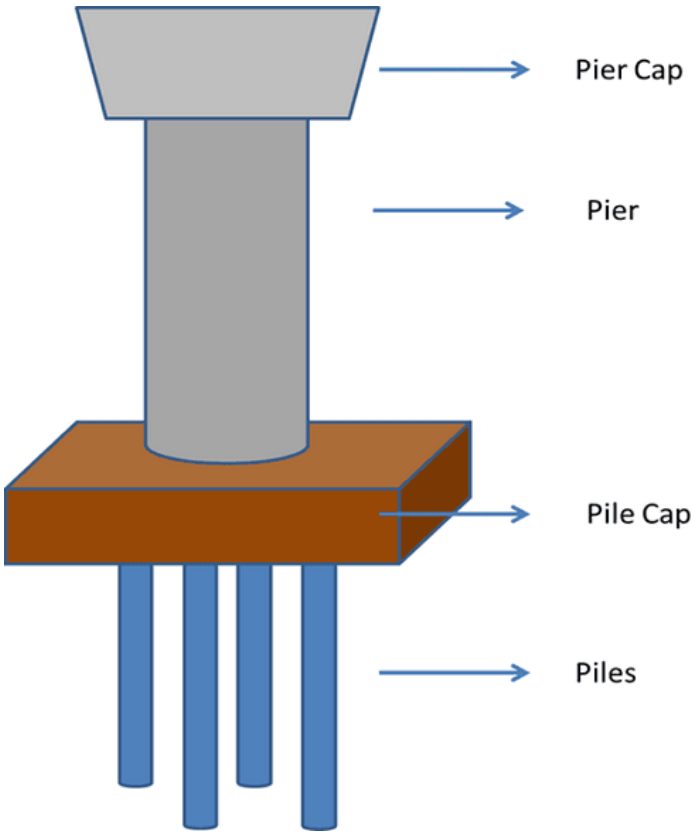


Figure: Pier Foundation

Pier foundation is a cylindrical structural member that transfers heavy load from the superstructure to the soil by end bearing. Unlike piles, it can only transfer load by bearing and by not skin friction.

Pier Foundation is economic when:

- ✓ Sound rock strata lie under a decomposed rock layer at the top.
- ✓ The topsoil is stiff clay that resists driving the bearing pile.
- ✓ When a heavy load is to be transferred to the soil.

Pier foundation has many advantages:

- ➢ It has a broad scope of assortment with regard to structure. There are different materials we can here to build a stylish view, and it stays in our spending limit.
- ➢ It sets aside cash and time as it doesn't require the broad removal of a ton of cement.
- ➢ Bearing limits can increment by under-reaming the base.

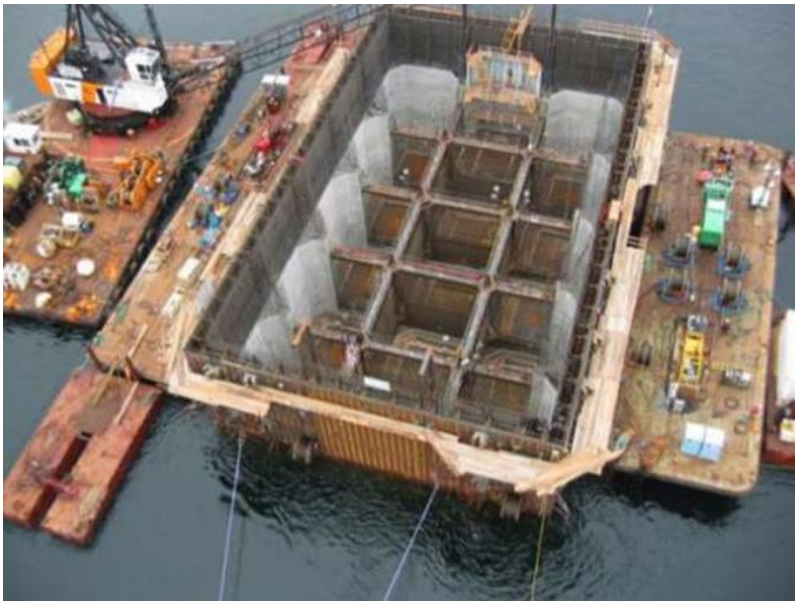
Along with the advantages, it has a few disadvantages as well:

1. If one post or dock is harmed, it can prompt critical harm to the general establishment.
2. It can be vitality wasteful if not protected appropriately.
3. Floors must be intensely, vigorously protected, and shielded from critters

3. Caisson Foundation

Caisson foundation is a watertight retaining structure used as a bridge pier, construction of the dam, etc. It is generally used in structures that require a foundation beneath a river or similar water bodies. The reason for choosing the caisson is that it can be floated to the desired location and then sunk into place.

A caisson foundation is a ready-made hollow cylinder depressed into the soil up to the desired level and then filled with concrete, which ultimately converts to a foundation. It is mostly used as bridge piers. Caissons are sensitive to construction procedures and lack construction expertise.



There are several types of caisson foundations.

1. Box Caissons.
2. Floating Caissons.
3. Pneumatic Caissons.
4. Open Caissons.
5. Sheeted Caissons.
6. Excavated Caissons.

Caisson foundations are economic when:

- ✓ The pile cap requirement is to be minimized.
- ✓ Noise and vibration needed to be reduced.
- ✓ It has to be placed beneath water bodies.
- ✓ Highly lateral and axial loading capacity is required