CHAPTER – 1

CIVIL ENGINEERING DECIPLINES AND BUILDING SCIENCE

INTRODUCTION

Engineering is the profession that puts scientific knowledge to practical use. i.e., Engineering is an applied science. Engineers look for better and optimized ways to use existing resources and often develop new resources & new materials.

In general, the field of engineering includes a wide variety of activities. Engineering projects range from the construction of huge dams to the design of tiny electronic circuits. Engineers may help to produce guided missiles, industrial robots, or artificial limbs for the physically handicapped. They develop complex scientific Equipments to explore the reaches of outer space and the depths of the oceans. Engineers also plan electric power and water supply systems, and deal with automobiles, television sets, and other consumer products.

They work to reduce environmental pollution, increase the world's food supply, and make transportation faster & safer.

Out of all branches of engineering, Civil Engineering is the one that is directly associated with the welfare of the society. 'Civil Engineering', a branch full of human activities, has been pursued from very early times when man began to adopt the environment to his needs. The motto of the civil engineering.

The term civil in civil engineering refers to the discipline's involvement in public works, including government buildings, military bases, mass transit systems (i.e., highways, railways, airports, and water ways), water treatment works, waste management, irrigation etc. In ancient times, there was no formal engineering education. The earliest engineers-built structures and developed tools by experience and by methods which were empirical in nature. However, the present-day engineering activities are based on sound theoretical knowledge. Guided by theory and the past experience, the present-day civil engineers work for the benefit of the society, carrying out the works according to certain standards. Maintaining the quality in their works help them to achieve good performance from their outputs.

SCOPE OF CIVIL ENGINEERING

The scope of Civil Engineering is very vast, and it has many diversified fields which help in the total development of any civilization. Various subdivisions that come under civil engineering branch are listed below.

- Surveying
- Building Materials Technology
- Geotechnical Engineering
- Structural Engineering
- Construction Technology
- Hydraulics
- Water Resources and Irrigation Engineering
- Transportation Engineering
- Environmental Engineering

A brief description of the contents of study of each of these sub-divisions is given below

- ***Surveying***

It is a field of specialization which involves processes through which the relative positions of various points are objects on the earth's surface are determined on a horizontal plane as well as on a vertical plane. The results of such processes are represented in the form of map or plan. A plan is a graphical representation of various ground features as projected on a horizontal plane, to some convenient scale, on a sheet of paper.

Surveying is an essential work which is carried out in the beginning of any constructional activity, such as development of an area, construction of transportation facilities such as road ways, railways and air field pavements, construction of structures such as buildings, bridges, dams and the like.

Conventional methods of surveying include chain surveying, compass surveying, theodolite surveying, plane table surveying and levelling. The modern day surveying, by virtue of developments in technology, include the use of sophisticated instruments like total station and other electronic, electro-magnetic, electro-optical instruments and tools such as Geographic Information System (GIS), Global Positioning System (GPS) and the like. It also makes use of allied fields such as remote sensing and photogrammetric.

• ***Building Materials Technology***

Any constructional activity invariably requires the use of different types of materials.
These materials of construction can be broadly classified in to

- Conventional materials (Ex: soil, stones, bricks, timber, cement / lime, tiles, plain and reinforced cement concrete, pre-stressed concrete).
- Modern building materials (Ex: Fibre reinforced concrete, aluminium, glazed tiles, plaster of Paris).
- Alternate building materials (Ex: Fly ash, polymeric materials, industrial wastes, recycled aggregates).
- Smart materials.

Depending upon the requirement, budget and other constraints, any combination of these materials can be used in the construction works. Building materials technology deals with a detailed study of these materials of construction origin / fabrication–/ manufacture, types, properties, functional advantages, limitations. These information help in judging the suitability of different materials to be used in the proposed constructional activity.

• ***Geotechnical Engineering***

All structures built on earth transfer the superimposed loads to the ground (soil / rock) underneath, through appropriate foundation. Soils are complex geological materials which are expected to receive the loads transferred to them safely without causing damage to the structure. The soils are physico-chemically active materials, and their engineering behaviour depends upon their water content. This subject encompasses

 a detailed study of soils –formation, composition, properties and their determination

 a detailed study of rocks–types, properties, strength and deformation characteristics and their determination.

 different types foundations, their relative merits and limitations, suitability and design aspects.

 design and analysis of various earth structures such as embankments, dams, retaining walls etc.

 site investigation, sub-soil exploration and field tests.

 Ground improvement techniques

Geotechnical earthquake engineering is a specialized field of geotechnical engineering, which deals with earthquakes, their effects on foundation soil, different types of seismic hazards, study of dynamic soil properties, seismic design of earth structures, soil improvement to withstand / minimize seismic hazards etc.

- ***Structural Engineering***

All structures constructed on this earth are subjected to various types of loads of different complexities / nature. Various components of a structure are expected to respond to these loads favorably and to withstand them safely. The satisfactory performance of structures requires the know ledge of materials' behaviour and selection of appropriate material for use, proportioning / designing different components of a structure, estimating the stresses developed in different component of a structure and back checking the design. This field includes subjects like engineering mechanics, strength of materials, structural analysis and design of structures. It also requires the knowledge of different tools to carry out the analysis and design of structural components such as matrix method of analysis, finite different techniques, finite element methodof analysis and the like.

- ***Construction Technology***

All activities undertaken in the construction of any structure come under this field. Construction of various types of structures, making use of various types of constructional materials available, study of different technologies of construction, management of various constructional activities with respect to different parameters like resources (material / human), time, finance and legal aspects are included in this field of civil engineering.

- ***Hydraulics***

Water is an integral part of human life and of almost all constructional activities. This subjectdeals with

- basic properties of water
- study of water at rest as well as in motionflow
- through pipes
- open channel flowsflow
- measurements
- different analytical, computational and experimental approaches to analyse theflow problems.

- ***Water Resources and Irrigation Engineering***

There are different sources of fresh water on this earth such as rain, ground water, streams / rivers. These

waters have to be harnessed and stored properly before they are utilized for different purposes such as drinking, irrigation and water power generation. This subject deals with

- different sources of water on this earth
- estimation of total water available and water requirement.
- construction and maintenance of structures to tap the available resources of water
- planning and building of water retaining structures such as tanks / dams construction and maintenance of water carrying structures
- different irrigation schemes flood
- control methodologies
- depletion and replenishment of water resources

- ***Transportation Engineering***

The social and economic development of any country is a function of transportation facilities available in that country. Different means of transportation include roadways, railways, air ways and water ways. This field deals with a detailed study of planning, design, construction and maintenance of different types of road ways, railways, airports and runways, harbours and docks, bridges and tunnels.

- ***Environmental Engineering***

This subject deals with

- study of available water quality and checking against the standards
- water collection and water purification through various treatment processes
- supply and distribution of quality water for urban and rural areas, for domestic and industrialusage
- study of domestic water supply system and sanitary systemwaste water
- collection, treatment and safe disposal
- study of wastes and waste management
- study of different kinds of pollution and pollution control measuresstudy of
- environmental safety

INFRASTRUCTURE

Infrastructure is a system of services and communication that is required for the over all development of the society. It refers to facilities such as transportation (i.e. Railways, Highways, Air ways, Water ways etc.,), hospitals, education; energy (coal, electricity, oil etc.), irrigation, farm equipments & machineries, science and technology, communication, health & hygiene, banking that facilitate and contribute in the

process of production of goods and services for the overall development of the economy of the society. The infrastructure is of two types.

a) **Economic infrastructure:** It contributes directly to the economic development of any country. It consists of transport and communication, power supply, irrigation networks, financial institutions etc.

b) **Social infrastructure:** It contributes to the process of economic development of any country indirectly. It consists of education & training, health & family welfare, housing & water supply and other civic amenities.

Transport and Communication:

In this modern age, transport along with electricity and power forms the basic infrastructural requirement for industrialization. Transport provides vital link between production centres and distribution points. It also exercises a unifying and integrating influence upon the economy. Indeed, transport facilitates agricultural development by supply of modern inputs like seeds, chemical fertilizers, pesticides, farm implements and machinery. Transport helps the movementof agricultural produce from scattered farms to the distant markets. It helps the industrial development by facilitating the regular and prompt movement of raw materials and labour to the factories and finished products to market. It helps to widen the market for wide variety ofindustrial goods. Transport helps to widen the market and trade. It facilitates exploitation of natural resources, helps the mobility of labour, and serves administration and defence requirements.

The important means of transport are railways, roadways, waterways and airways. The importance of transport services in economy depends on several economic factors such as interdependence, mutual co-operation and co-existence of different regions. Therefore, to integrate diversified economic regions within the country and economies of the world, a well-developed network of transport system is of vital importance.

Railways provide an economical mode of transport for freight over long distances. The roadways are most ideal transport for short distance travel and light freight and to cater to diverse points of production, distribution and consumption. Well-constructed roads have become main components of economic infrastructure today. The other main components of transport networkin the economy along with roads and railways are coastal shipping, inland waterways and domestic airlines.

Communication means imparting or transmission of information. The difference between transport and communication is that while the former implies the conveyance of goods and passengers from one place to another, the latter implies the conveyance of information. The conveyance of information is necessary for the development of industry, commerce and trade of any country. Today, a very large network of communication media exists. These include postal

services, telegraph and the telephone, radio and television (Door Darshan), tele printers, telex, fax services, the cinema and the press. The responsibility of building and extending the services is fixed to specialized departments and agencies like postal department, telegraph department etc.

The communication network is also claimed to be formed under social infrastructure of the economy. Communication can also be seen as a service in imparting education.

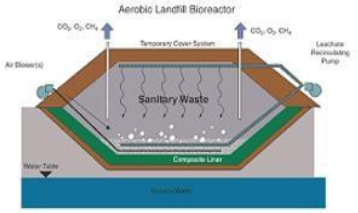
GEOTECHNICAL, WATER RESOURCES AND ENVIRONMENTALENGINEERING

GEOTECHNICAL ENGINEERING:

- Geotechnical Engineering is the study of rock and soil supporting Civil Engineering systems.
- Identification of soil properties presents challenges to geotechnical engineers as the soil properties vary from place to place and with depth.
- The material properties and behavior of soil are difficult to predictdue to its variability and limitation on investigation.
- It involves in the design of foundations, tunnels, embankments, dams, retaining walls, stability of natural slopes, mining, petroleumexploration, offshore structures, landfills etc.

TUNNELS, EARTHEN EMBANKMENTS AND DAMS

DESIGN OF RETAINING WALLS, SOIL SLOPES, MINING & FOUNDATIONS OF OFFSHORE STRUCTURES

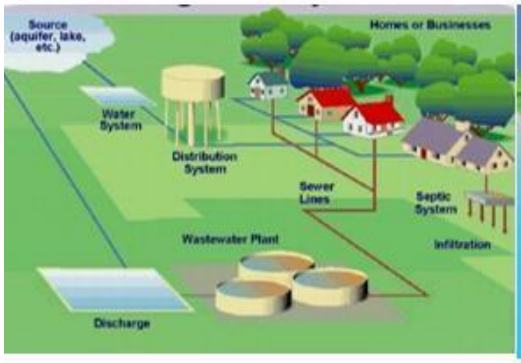


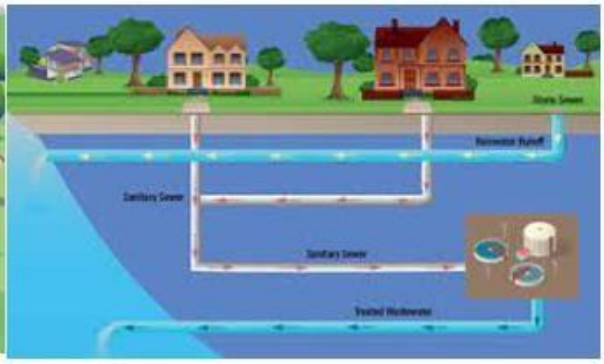
DESIGN OF LANDFILLS & GROUND IMPROVEMENT

WATER RESOURCES ENGINEERING

- Water Resources Engineering is the quantitative study of the hydrologic cycle. It is concerned with the collection and management of water (as a natural resource).
- As a discipline it therefore combines elements of hydrology, environmental science, meteorology, conservation and resource management.
- This area of Civil Engineering relates to the prediction and management of both the quality and quantity of water in both ground and surface water resources.
- Applications include the management of the urban water supply, the design of urban storm – sewer systems, flood forecasting, design of hydraulic structures, irrigation systems etc.

APPLICATIONS OF WATER RESOURCES ENGINEERING

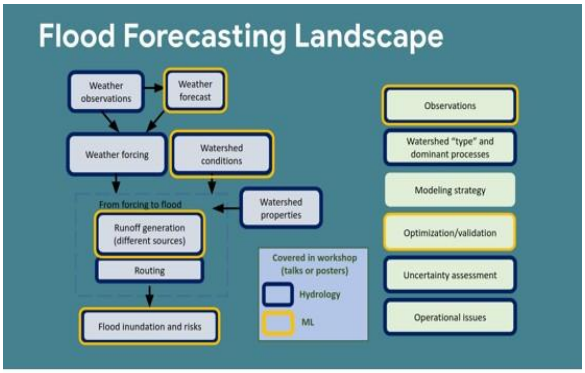




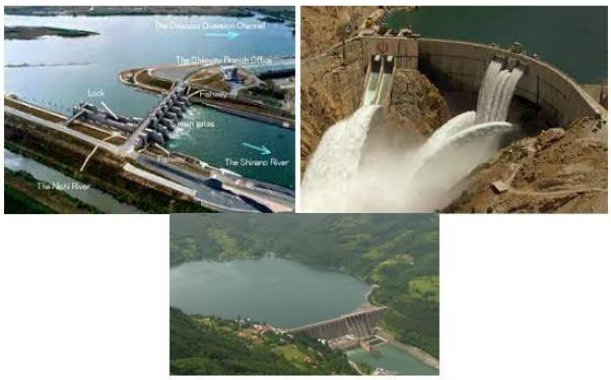
WATER SUPPLY SYSTEM

SEWER SYSTEM

DESIGN OF WATER SUPPLY AND SEWER SYSTEMS



FLOOD FORECASTING



DESIGN OF HYDRAULIC STRUCTURES

DESIGN OF IRRIGATION SYSTEMS

ENVIRONMENTAL ENGINEERING

- It involves waste management, waste disposal systems, pollution control, environmental sustainability, public health, water supply and treatment, waste water treatment, water resources management, air pollution management, pollutant transport, hazardous waste management etc.

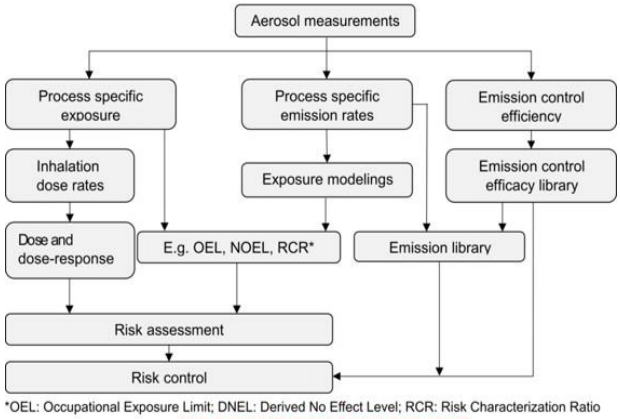
- Applications include quantification of different types of pollutants, fixing standards for effluents, monitoring / prevention of different types of pollution, environmental impact assessment for factories and industries, conservation and preservation of natural resourcesand environment, design and construction of pipe lines etc.

- Environmental engineering also deals with the remediation of contaminated sites after waste disposal or accidental contamination.

- Environmental engineers administer pollution reduction, green engineering, industrial ecology and compile information on environmental consequences of proposed actions.

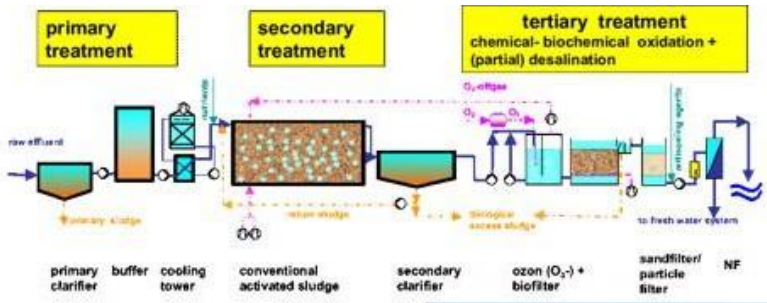
APPLICATIONS OF ENVIRONMENTAL ENGINEERING

WASTE MANAGEMENT



*OEL: Occupational Exposure Limit; DNEL: Derived No Effect Level; RCR: Risk Characterization Ratio

AIR POLLUTION MANAGEMENT



WASTE WATER TREATMENT

HAZARDOUS WASTE MANAGEMENT

REMEDIATION OF CONTAMINATED SITES

GREEN BUILDING TECHNIQUES

Construction Planning and Project Management

Planning, scheduling is an important part of the construction management. Planning and scheduling of construction activities helps engineers to complete the project in time and within the budget. The term ‘Construction’ does not only denote physical activities involving men, materials and machinery but also covers the entire gamut of activities from conception to realization of a construction project. Thus, management of resources such as men, materials, machinery requires effective planning and scheduling of each activity.

Management is the science and art of planning, organizing, leading and controlling the work of organization members and of using all available organization resources to reach stated organizational goals. Construction management deals with economical consumption of the resources available in the least possible time for successful completion of construction project. ‘Men’, ‘materials’, ‘machinery’ and ‘money’ are termed as resources in construction Management.

Objectives of Construction Management:

The main objectives of construction management are,

- Completing the work within estimated budget and specified time.
- Maintaining a reputation for high quality workmanship
- Taking sound decisions and delegation of authority
- Developing an organization that works as a team.

Functions of Construction Management:

The functions of construction Management are

1. Scoping
2. Planning
3. Estimating
4. Scheduling
5. Organizing
6. Staffing
7. Directing
8. Controlling & Coordinating.

1. Scoping

The scoping function is an activity that covers the boundaries of the realm of work that must be done so that the project is completed.

2. Planning

The planning function is the activity of identifying the desired project objectives, reducing the opportunity for the risk to arise, anticipating the work to be completed on time so it can finally be produced as a product or service that has been mutually agreed upon.

3. Estimating

The estimating function is part of a form of project planning whose activities include quantitative estimates of project costs, resources used, to the duration of project completion.

4. Scheduling

The scheduling function is the activity of compiling a list of activities that includes the start and finish time of each job, the ideal completion duration, and the person in charge of each type of work. Effective scheduling is an important factor to create good time management.

5. Organizing

The organizing function is an activity to confirm or ensure that all team members are fully aware of their respective roles, responsibilities, and their relationship with you as the project manager.

6. Directing

The directing function centers on the leadership style of a project. This directing activity includes instructing, mentoring, and training team communication in order to achieve the project goals.

7. Controlling

The controlling function is the activity of controlling all work that takes place in the project so that it goes according to plan or does not deviate. The project manager will use the standard measurement matrix to monitor each ongoing activity. This function can be said to be the most difficult and important function because it determines the effectiveness and success of the project.

8. Closing

The closing function is an activity of evaluating and scoring the final results of projects that have ended.

Brick

A brick is a type of block used to build walls, pavements and other elements in masonry construction. Properly, the term brick denotes a block composed of dried clay, but is now also used informally to denote other chemically cured construction blocks. Bricks can be joined using mortar, adhesives or by interlocking them. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities.

A brick is an important construction material which is generally available in rectangular shape manufactured from clay. They are very popular from olden days to modern days because of low cost and durability.

Classification of bricks

Different types of bricks are used in masonry construction based on material such as clay,

concrete, lime, fly ash etc. Filed field identification of bricks for their properties, uses and suitability for different construction works are important.

Based on the manufacturing process, bricks are broadly classified into two types,

1. Sun-Dried or unburnt bricks

2. Burnt bricks

1. Sun-Dried or Unburnt Clay Bricks

Sun-dried or unburnt bricks are less durable and these are used for temporary structures. Unburnt bricks preparation involved in 3 steps they are preparation of clay, molding and drying. After molding, bricks are subjected to sunlight and dried using heat from sun. So, theyare not that much strong and they also have less water resistance and less fire resistance. Thesebricks are not suitable for permanent structures.

2. Burnt Clay Bricks

Burnt bricks are good quality bricks but however they also consist some defected bricks. So, burnt bricks are classified into four types and they are

a) First class bricks
b) Second class bricks
c) Third class bricks
d) Fourth class bricks

a) **First class bricks:** First class bricks are good quality bricks compared to other classes. They are molded by table-molding and burnt in large kilns. So, these bricks contain standard shape, sharp edges and smooth surfaces. They are more durable and having more strength. They can be used for permanent structures. However, because of their good properties they are costly than other classes.

b) **Second class bricks:** Second class bricks are moderate quality bricks and they are molded by ground-molding process. These bricks are also burnt in kilns. But because of ground molding, they do not have smooth surfaces as well as sharp edges. The shape of bricks also irregular due to unevenness in ground. These also will give best results in strength and durability.

c) **Third class bricks:** Third class bricks are poor quality bricks which are generally used for temporary structures like unburnt bricks. These are not suitable for rainy areas. They are ground-molded type bricks and burnt in clamps. The surface of this type of bricks are rough and they have unfair edges.

d) **Fourth class bricks:** Fourth class bricks are very poor-quality bricks and these are not used as bricks in the structure. They are crushed and used as aggregates in the manufacturing of concrete. They are obtained by over burning, because of this they get overheated and obtains brittle nature. So, they can break easily and not suitable for construction purpose.

a) First class bricks

b) Second class bricks

c) Third class bricks

d) Fourth class bricks

Identification of Bricks Quality at Construction Site

1. To build a good quality structure, observing quality of materials is important. Here we discuss about how good bricks are identified at construction site.
2. The color of bricks should be bright and uniform.
3. They should be well burned and having smooth surfaces and sharp edges.

4. Thermal conductivity of bricks should be less and they should be sound proof.
5. They shouldn't absorb more than 20% by weight when we placed it in water.
6. When we struck two bricks together, ringing sound should be delivered.
7. Structure of bricks should be homogeneous and uniform.
8. The bricks should not break when we dropped it form 1m height.
9. There should not be any scratch left on the brick when we scratched with finger nail.
10. There should not be any white deposits on brick, when we soaked it in water for 24 hrs.

Qualities of a Good Brick Properties of good brick

1. **Brick Earth**
   Brick earth should be free from pebbles (kankars), stones, organic matter, saltpeter (potassium nitrate) and other harmful chemical, as it makes poor quality of bricks.
2. **Size of a Brick**
   A good brick should have a uniform size with plain and rectangular surfaces and should be parallel from the sides having sharp and straight edges, as per standards. A brick should not exceed 3 mm tolerance in length and 1.5 mm tolerance in width and height. According to 'IS 1077: 1992' (Common Burnt Clay Building Bricks – Specification), the standard or conventional size of clay brick is 190mm X 90mm x 90mm. However, the size of bricks may vary from country to country and from place to place even in big countries like India.
3. **Shape**
   The shape of a brick should be uniform. The edges of a good brick should be sharp, straight and at a right angle. However, bricks used for special purpose may be either cut or manufactured in various other shapes. These are generally modifications of rectangular shapes.
4. **Colour**
   There are wide range of colours, such as red, white, grey, brown, purple, blue and black, along with some intermediate shades. According to 'W. B. McKay' (Author of Building Construction), the colour is influenced by the chemical constitution of the clay, its temperature while burning, the atmospheric condition of kiln, and staining. Good quality bricks should be well burnt and should have a uniform colour throughout the body of brick. Over burnt and under burnt bricks loses the uniformity of colour on its surface and strength. Very dark shades of red indicate over burnt bricks whereas, yellow colour indicates under burnt bricks.
5. **Frog in Brick**
   A good quality brick should have a proper frog (Depression made on the face of bricks during moulding), so that the mortar can be properly filled in the frog. The size of the frog should be 100 mm in length, 40 mm in width and 10 mm in depth.
6. **Texture and Compactness**
   There is a considerable variation in the texture of bricks. The good bricks should have a pre-compacted and uniform texture. The surfaces of brick should not be too smooth to cause slipping of mortar. A fractured surface should not show cracks, holes, grits or lumps of lime.
7. **Compressive Strength**
   The compressive strength of brick depends upon the composition of the clay and degree of burning. As per 'National Building Code of India' (1983), the compressive strength of brick should be of minimum 3.5 N/mm^2 i.e. 35 Kg/cm^2. We have also written an article on how to check the compressive strength of brick.
8. **Hardness**

Bricks should be sufficiently hard. No impression should be left on the surface of a brick when it is scratched with fingernails.

9. **Water Absorption**
   Water absorption of a good brick should not exceed 20 % of its dry weight when immersed in water for 24 hours. Bricks, when soaked in water for 24 hours, should not show deposits of white salts, when allowed to dry in the shade. Bricks should not absorb water more than 20 per cent by weight especially for bricks of the first class and 22 per cent by weight for bricks of the second class when they are soaked in water for 24 hours. Testing should be done in the laboratory in order to check water absorption of brick.
10. **Soundness**
    When the brick is struck with a hammer or with another brick, it should give a metallic ringing sound.
11. **Efflorescence:** Bricks should not show white patches when soaked in water for 24 hours and then allowed to dry in shade. White patches are due to the presence of sulphate of calcium, magnesium and potassium. They keep the masonry permanently in damp and wet conditions.
12. **Thermal Conductivity:** Bricks should have low thermal conductivity, so that buildings built with them are cool in summer and warm in winter.
13. **Sound Insulation:** Heavier bricks are poor insulators of sound while light weight and hollow bricks provide good sound insulation.
14. **Fire Resistance:** Fire resistance of bricks is usually good. In fact, bricks are used to encase steel columns to protect them from fire.

Field and Laboratory tests on Bricks

Field Test of Bricks

1. Shape and Size Test

Good quality of bricks should have a uniform in size and have rectangular faces. It shall be checked by doing observation.

2. Colour Test

Good quality of Bricks should have a uniform in colour throughout. A check shall be made before purchasing the bricks.

3. Sound Test

Bricks should have a metallic ring when one brick stuck against another brick. The dull sound shows a bad quality.

4. Structure

Bricks should be free from holes, lumps, or grit.

Broken bricks if observed shall be removed and not be used for masonry work.

5. Hardness Test

In this test, scratch shall be done on bricks with a nail. If no impression is marked on the surface that shows good quality and adequate hard surfaces.

6. Efflorescence Test

Bricks shall be placed in a glass dish having water to a height of 25 mm in a well-ventilated room. After some hours, water is absorbed or gets evaporated; again, water is added for a depth of 1 inch. After the second evaporation, a white/grey patch is observed in bricks. Efflorescence shall be reported as ‘

Nil: No patches.

Slight: Not more than 10% of the area covered with deposit salts.

Moderate: 10 to 50% of area bricks but unaccompanied by powdering or flaking of the surface.

Laboratory Test of Bricks

1. Dimension Test of Bricks

Following are the procedure of Dimension test of bricks

- In this test, twenty numbers of bricks shall be randomly selected from the stack sample.
- Loose particles of clay, sand, and blisters shall be removed from the surface of bricks.
- All the bricks shall be arranged on the leveled surface. All bricks shall be close with each other and should be in a straight line.
- The length of the laid 20 bricks shall be measured with Measurement Tape. If found any kind of technical problem to measure the bricks in one row, then a sample of 20 bricks shall be divided in two-row of 10 bricks each which shall be measured separately.
- Measurement shall be done in lengthwise, widthwise, and height wise separately.
- The tolerance in the dimension of the 20 bricks shall be within the following limits.

For Modular Size of Bricks **(**190 mm x 90 mm x 90 mm and 190 mm x 90 mm x 40 mm)	**Measurements of 20 bricks**	**Tolerance Value**
Along Length	190 x 20 = 3800 mm	3800 mm + 80 mm
Along width	90 x 20 = 1800 mm	1800 mm + 40 mm
For 90 mm height bricks	90 x 20 = 1800 mm	1800 mm + 40 mm
For 40 mm height bricks	40 x 20 = 800 mm	1800 mm + 40 mm
For Modular Size of Bricks **(**230 mm x 110 mm x 70 mm and 230 mm x 110 mm x 30 mm**)**	**Measurements of 20 bricks**	**Tolerance Value**
Along Length	230 x 20 = 4600 mm	4600 mm + 80 mm
Along width	110 x 20 = 2200 mm	2200 mm + 40 mm
For 70 mm height bricks	70 x 20 = 1400 mm	1400 mm + 40 mm
For 30 mm height bricks	30 x 20 = 800 mm	mm + 40 mm

2. Water absorption Test

Following are the procedure of water absorption test of bricks:

Code of Reference: IS 3495 (Part 2): 1992.

Apparatus required: Weighing Balance, Specimen, and oven dry.

- The specimen shall be dried in an oven-dry at a temperature of 105 to 1150 C till it achieves substantially constant mass.
- The specimen shall be cooled to room temperature of 27+20 C.
- After cooling the specimen in Room temperature and measure the weight of the specimen say (W1).
- Now the dried specimen shall be immersed in a clean temperature of 27+20 C for up to 24 hours.
- The specimen shall be removed after 24 hours and wipe out with dry clothes and

measure the weight say W2. The weighing of the specimen shall be completed within 3 minutes after removal from water.

- Water absorption in percentage after 24-hour immersion in cold water is calculated by the following formula
    - Water absorption (%) = (W2-W1/W1) x 100
- It shall not be more than 20% by weight up to class 12.5 and 15 percent by weight of higher classes.

3. Compressive Strength of Bricks

The procedure of compressive strength test of bricks are as follows;

Code of Reference: IS 3495 (Part 2): 1992.

Apparatus required: Compression Testing Machine (CTM), Specimen.

- Brick is immersed in water at room temperature for 24 hours. It shall be removed and drain out any surplus moisture at room temperature.
- The frog of bricks is filled flush with 1 part of cement and 3 part of sand.
- The specimen shall be stored under the damp jute bags for 24 hours and immersed in clean water for 24 hours and then wipe out the moisture with dry clothes.
- Brick is then placed on a compressive testing machine with 6 mm plywood on top and bottom of it in order to get a uniform load on the specimen.
- The Axial load then be applied at a uniform rate of 14 N/mm2 per minute till the failure occurs. The maximum load at failure is noted.
- The load at failure shall be the maximum load at which the specimen fails to produce a further increase in the indicator reading on the testing machine.
- The compressive strength of bricks is the ratio of maximum load at failure in N to the Area of the bed faces in mm^2. The average specimen is taken as compressive strength.
- Minimum average compressive strength for various classes

Class Designation	Average Compressive Strength not less than (N/mm^2)
35	35
30	30
25	20
17.5	17.5
15	15
12.5	12.5
10	10
7.5	7.5
5	5
3.5	3.5

As per IS 1077-1976, bricks compressive strength shall not be less than 3.5 N/mm2.

Advantages of Bricks

- Economical (Raw material is easily available)
- Hard and durable
- Compressive strength is good enough for ordinary construction
- Different orientations and sizes give different surface textures
- Very low maintenance cost is required
- Demolishing of brick structures is very easy, less time consuming and hence economic
- Reusable and Recyclable
- Highly fire resistant
- Produces less environmental pollution during manufacturing process

Disadvantages of Bricks

- Time consuming construction
- Cannot be used in high seismic zones
- Since bricks absorb water easily, therefore, it causes fluorescence when not exposed to air
- Very Less tensile strength
- Rough surfaces of bricks may cause mold growth if not properly cleaned
- Cleaning brick surfaces is a hard job
- Colour of low-quality brick changes when exposed to sun for a long period of time

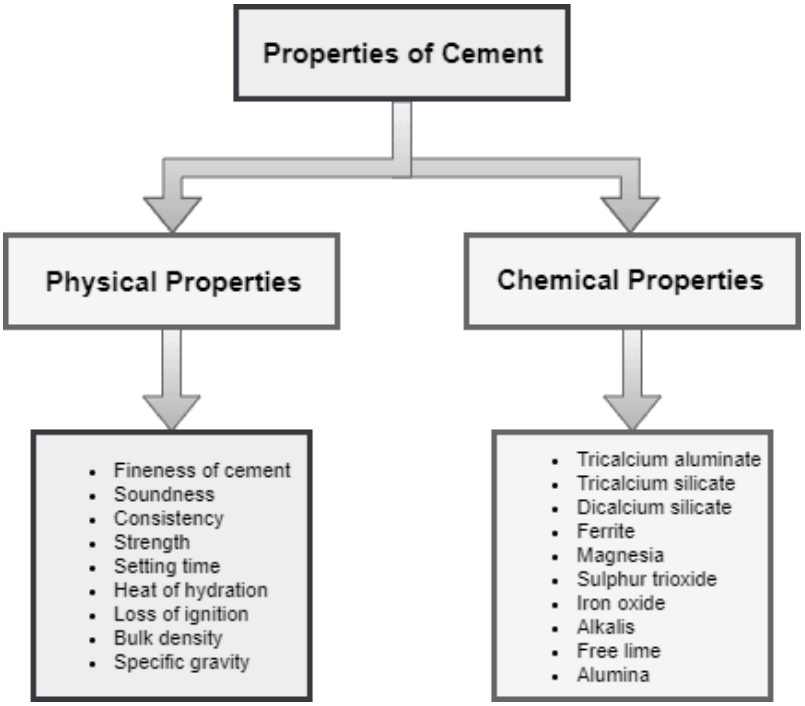
Cement

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together.

Cements used in construction are usually inorganic, often lime or calcium silicate based, which can be characterized as non-hydraulic or hydraulic respectively, depending on the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster).

Non-hydraulic cement does not set in wet conditions or under water. Rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.

Properties of Cement



Physical Properties of Cement

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of good cement are based on:

- Fineness of cement
- Soundness
- Consistency
- Strength
- Setting time
- Heat of hydration
- Loss of ignition
- Bulk density
- Specific gravity (Relative density)

These physical properties are discussed in details in the following segment. Also, you will find the test names associated with these physical properties.

Fineness of Cement

The size of the particles of the cement is its fineness. The required fineness of good cement is achieved through grinding the clinker in the last step of cement production process. As

hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.

Soundness of Cement

Soundness refers to the ability of cement to not shrink upon hardening. Good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia.

Tests:

Unsoundness of cement may appear after several years, so tests for ensuring soundness must be able to determine that potential.

- **Le Chatelier Test**
  This method, done by using Le Chatelier Apparatus, tests the expansion of cement due to lime. Cement paste (normal consistency) is taken between glass slides and submerged in water for 24 hours at 20+1°C. It is taken out to measure the distance between the indicators and then returned underwater, brought to boil in 25-30 mins and boiled for an hour. After cooling the device, the distance between indicator points is measured again. In a good quality cement, the distance should not exceed 10 mm.
- **Autoclave Test**
  Cement paste (of normal consistency) is placed in an autoclave (high-pressure steam vessel) and slowly brought to 2.03 MPa, and then kept there for 3 hours. The change in length of the specimen (after gradually bringing the autoclave to room temperature and pressure) is measured and expressed in percentage. The requirement for good quality cement is a maximum of 0.80% autoclave expansion. Standard autoclave test: AASHTO T 107 and ASTM C 151: Autoclave Expansion of Portland Cement.

Consistency of Cement

The ability of cement paste to flow is consistency.

It is measured by **Vicat Test.**

In Vicat Test Cement paste of normal consistency is taken in the Vicat Apparatus. The plunger of the apparatus is brought down to touch the top surface of the cement. The plunger will penetrate the cement up to a certain depth depending on the consistency. A cement is said to have a normal consistency when the plunger penetrates 10±1 mm.

Strength of Cement

Three types of strength of cement are measured – compressive, tensile and flexural. Various factors affect the strength, such as water-cement ratio, cement-fine aggregate ratio, curing conditions, size and shape of a specimen, the manner of molding and mixing, loadingconditions and age. While testing the strength, the following should be considered:

- Cement mortar strength and cement concrete strength are not directly related. Cement strength is merely a quality control measure.
- The tests of strength are performed on cement mortar mix, not on cement paste.
- Cement gains strength over time, so the specific time of performing the test should be mentioned.

Compressive Strength

It is the most common strength test. A test specimen (50mm) is taken and subjected to a compressive load until failure. The loading sequence must be within 20 seconds and 80 seconds.

Standard tests:

i. AASHTO T 106 and ASTM C 109: Compressive Strength of Hydraulic Cement Mortars (Using 50-mm or 2-in. Cube Specimens)
ii. ASTM C 349: Compressive Strength of Hydraulic Cement Mortars (Using Portions of Prisms Broken in Flexure)

Tensile strength

Though this test used to be common during the early years of cement production, now it does not offer any useful information about the properties of cement.

Flexural strength

This is actually a measure of tensile strength in bending. The test is performed in a 40 x40 x 160 mm cement mortar beam, which is loaded at its centre point until failure.

Standard test:

i. ASTM C 348: Flexural Strength of Hydraulic Cement Mortars

Setting Time of Cement

Cement sets and hardens when water is added. This setting time can vary depending on multiple factors, such as fineness of cement, cement-water ratio, chemical content, and admixtures. Cement used in construction should have an initial setting time that is not too low and a final setting time not too high. Hence, two setting times are measured:

- Initial set: When the paste begins to stiffen noticeably (typically occurs within 30-45 minutes)
- Final set: When the cement hardens, being able to sustain some load (occurs below 10 hours)

Again, setting time can also be an indicator of hydration rate.

Standard Tests:

i. AASHTO T 131 and ASTM C 191: Time of Setting of Hydraulic Cement by Vicat Needle
ii. AASHTO T 154: Time of Setting of Hydraulic Cement by Gillmore Needles
iii. ASTM C 266: Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

Heat of Hydration

When water is added to cement, the reaction that takes place is called hydration. Hydration generates heat, which can affect the quality of the cement and also be beneficial in maintaining curing temperature during cold weather. On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress. The heat of hydration is affected most by C_3S and C_3A present in cement, and also by water-cement ratio, fineness and curing temperature. The heat of hydration of Portland cement is calculated by determining the difference between the dry and the partially hydrated cement (obtained by comparing these at 7th and 28th days).

Standard Test:

ASTM C 186: Heat of Hydration of Hydraulic Cement

Loss of Ignition

Heating a cement sample at 900 - 1000°C (that is, until a constant weight is obtained) causes weight loss. This loss of weight upon heating is calculated as loss of ignition. Improper and prolonged storage or adulteration during transport or transfer may lead to pre-hydration and carbonation, both of which might be indicated by increased loss of ignition.

Standard Test:

AASHTO T 105 and ASTM C 114: Chemical Analysis of Hydraulic Cement

Bulk density

When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage. The density of cement may be anywhere from 62 to 78 pounds per cubic foot.

Specific Gravity (Relative Density)

Specific gravity is generally used in mixture proportioning calculations. Portland cement has a specific gravity of 3.15, but other types of cement (for example, Portland-blast-furnace-slag and Portland-pozzolan cement) may have specific gravities of about 2.90.

Standard Test:

AASHTO T 133 and ASTM C 188: Density of Hydraulic Cement

Chemical Properties of Cement

The raw materials for cement production are limestone (calcium), sand or clay (silicon), bauxite (aluminium) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnaceslag, slate. Chemical analysis of cement raw materials provides insight into the chemical properties of cement.

1. **Tricalcium aluminate (C3A)**
   Low content of C3A makes the cement sulphate-resistant. Gypsum reduces the hydration of C_3A, which liberates a lot of heat in the early stages of hydration. C3A does not provide any more than a little amount of strength. Type I cement: contains up to 3.5% SO_3 (in cement having more than 8% C_3A) Type II cement: contains up to 3% SO_3 (in cement having less than 8% C_3A)
2. **Tricalcium silicate (C_3S)**
   C3S causes rapid hydration as well as hardening and is responsible for the cement's early strength gain an initial setting.
3. **Dicalcium silicate (C_2S)**
   As opposed to tricalcium silicate, which helps early strength gain, dicalcium silicate in cement helps the strength gain after one week.
4. **Ferrite (C_4AF)**
   Ferrite is a fluxing agent. It reduces the melting temperature of the raw materials in the kiln from 3,000°F to 2,600°F. Though it hydrates rapidly, it does not contribute much to the strength of the cement.

5. **Magnesia (MgO)**
   The manufacturing process of Portland cement uses magnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement unsound and expansive, but a little amount of it can add strength to the cement. Production of MgO-based cement also causes less CO2 emission. All cement is limited to a content of 6% MgO.
6. **Sulphur trioxide**
   Sulphur trioxide in excess amount can make cement unsound.
7. **Iron oxide/ Ferric oxide**
   Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the colour of the cement.
8. **Alkalis**
   The amounts of potassium oxide (K_2O) and sodium oxide (Na_2O) determine the alkali content of the cement. Cement containing large amounts of alkali can cause some difficulty in regulating the setting time of cement. Low alkali cement, when used with calcium chloride in concrete, can cause discoloration. In slag-lime cement, ground granulated blast furnace slag is not hydraulic on its own but is "activated" by addition of alkalis. There is an optional limit in total alkali content of 0.60%, calculated by the equation $Na_2O + 0.658\ K_2O$.
9. **Free lime**
   Free lime, which is sometimes present in cement, may cause expansion.
10. **Silica fumes**
    Silica fume is added to cement concrete in order to improve a variety of properties, especially compressive strength, abrasion resistance and bond strength. Though setting time is prolonged by the addition of silica fume, it can grant exceptionally high strength. Hence, Portland cement containing 5-20% silica fume is usually produced for Portland cement projects that require high strength.
11. **Alumina**
    Cement containing high alumina has the ability to withstand frigid temperatures since alumina is chemical-resistant. It also quickens the setting but weakens the cement.

Field Tests of Cement

Date of Manufacturing: As the strength of cement reduces with age, the date of manufacturing of cement bags should be checked.

Cement Colour: The colour of cement should be uniform. It should be typical cement color i.e., grey colour with a light greenish shade.

Presence of lumps: Cement should be free from hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere.

Temperature Inside Cement Bag: If the hand is plunged into a bag of cement, it should be cool inside the cement bag. If hydration reaction takes place inside the bag, it will become warm.

Smoothness Test: When cement is touched or rubbed in between fingers, it should give a smooth feeling. If it felt rough, it indicates adulteration with sand.

Water Sinking Test: If a small quantity of cement is thrown into the water, it should float some time before finally sinking.

The smell of Cement Paste: A thin paste of cement with water should feel sticky between the fingers. If the cement contains too much-pounded clay and silt as an adulterant, the paste will give an earthy smell.

Glass Plate Test: A thick paste of cement with water is made on a piece of a glass plate and it is kept under water for 24 hours. It should set and not crack.

Block Test: A 25mm × 25mm × 200mm (1" ×1" ×8") block of cement with water is made. The block is then immersed in water for three days. After removing, it is supported 150mm apart and a weight of 15kg uniformly placed over it. If it shows no sign of failure the cement is good.

LABORATORY TESTS ON CEMENT

The following tests are conducted on cement in the laboratory (IS: 4031 – PT 1 to 15, 1989):

1. Fineness Test
2. Consistency Test
3. Setting Time Test
4. Strength Test
5. Soundness Test
6. Tensile Strength Test
7. Heat of Hydration Test
8. Chemical Composition Test

Types of Cement

1. Ordinary Portland Cement (OPC)

Ordinary Portland cement is the most widely used type of cement, which is suitable for all general concrete construction. It is the most commonly produced and used type of cement around the world, with annual global production of around 3.8 million cubic meters per year. This cement is suitable for all kinds of concrete construction.

2. Portland Pozzolana Cement (PPC)

Portland pozzolana cement is prepared by grinding pozzolanic clinker with Portland cement. It is also produced by adding pozzolana with the addition of gypsum or calcium sulfate or by intimately and uniformly blending Portland cement and fine pozzolana.

This cement has a high resistance to various chemical attacks on concrete compared with ordinary portland cement, and thus, it is widely used. It is used in marine structures, sewage works, sewage works, and for laying concrete underwater, such as bridges, piers, dams, and mass concrete works, etc.

3. Rapid Hardening Cement

Rapid hardening cement attains high strength in the early days; it is used in concrete where formworks are removed at an early stage and are similar to ordinary Portland cement (OPC). This cement has increased lime content and contains higher c3s content and finer grinding, which gives higher strength development than OPC at an early stage.

The strength of rapid hardening cement at the three days is similar to 7 days strength of OPC with the same water-cement ratio. Thus, the advantage of this cement is that formwork can be removed earlier, which increases the rate of construction and decreases the cost of construction by saving formwork cost. Rapid hardening cement is used in prefabricated concrete construction, road works, etc.

4. Quick setting cement

The difference between the quick setting cement and rapid hardening cement is that quick-setting cement sets earlier. At the same time, the rate of gain of strength is similar to Ordinary Portland Cement, while quick hardening cement gains strength quickly. Formworks in both cases can be removed earlier.
Quick setting cement is used where works is to be completed in very short period and for concreting in static or running water.

5. Low Heat Cement
Low heat cement is produced by maintaining the percentage of tricalcium aluminate below 6% by increasing the proportion of C2S. A small quantity of tricalcium aluminate makes the concrete to produce low heat of hydration. Low heat cement suitable for mass concrete construction like gravity dams, as the low heat of hydration, prevents the cracking of concrete due to heat.
This cement has increased power against sulphates and is less reactive and initial setting time is greater than OPC.

6. Sulfates Resisting Cement
Sulfate resisting cement is used to reduce the risk of sulfate attack on concrete and thus is used in the construction of foundations where the soil has high sulfate content. This cement has reduced the contents of C3A and C4AF.
Sulfate resisting cement is used in construction exposed to severe sulfate action by water and soil in places like canals linings, culverts, retaining walls, siphons, etc.

7. Blast Furnace Slag Cement
Blast furnace slag cement is obtained by grinding the clinkers with about 60% slag and resembles more or less in properties of Portland cement. It can be used for works where economic considerations are predominant.

8. High Alumina Cement
High alumina cement is obtained by melting a mixture of bauxite and lime and grinding with the clinker. It is a rapid hardening cement with initial and final setting time of about 3.5 and 5 hours, respectively.
The compressive strength of this cement is very high and more workable than ordinary portland cement and is used in works where concrete is subjected to high temperatures, frost, and acidic action.

9. White Cement
It is prepared from raw materials free from Iron oxide and is a type of ordinary portland cement, which is white. It is costlier and is used for architectural purposes such as precast curtain wall and facing panels, terrazzo surface, etc. and for interior and exterior decorative work like external renderings of buildings, facing slabs, floorings, ornamental concrete products, paths of gardens, swimming pools, etc.

10. Colored cement
It is produced by mixing 5- 10% mineral pigments with ordinary cement. They are widely used for decorative works on floors.

11. Air Entraining Cement
Air entraining cement is produced by adding indigenous air-entraining agents such as resins, glues, sodium salts of sulfates, etc. during the grinding of clinker.
This type of cement is especially suited to improve the workability with a smaller water-cement ratio and to improve frost resistance of concrete.

12. Expansive Cement
Expansive cement expands slightly with time and does not shrink during and after the time of hardening. This cement is mainly used for grouting anchor bolts and prestressed concrete ducts.

13. Hydrographic cement

Hydrographic cement is prepared by mixing water-repelling chemicals and has high workability and strength. It has the property of repelling water and is unaffected during monsoon or rains.

Hydrophobic cement is mainly used for the construction of water structures such as dams, water tanks, spillways, water retaining structures, etc.

Mortar

The term mortar is used to indicate a paste prepared by adding a required quantity of water to a mixture of binding material like cement or lime and fine aggregate like sand. This is used to bond masonry or other structural units.

The following are the major functions of mortar:

1. To bind building materials such as bricks and stones into a solid mass.
2. To carry out pointing and plasterwork on exposed surfaces of masonry.
3. To form an even and soft bedding layer for building units.
4. To form joints of pipes.
5. To improve the general appearance of a structure.
6. To prepare moulds for coping, corbels, cornice, etc.
7. To serve as a matrix or cavity to hold the coarse aggregates, etc.

Qualities or properties of mortar: -

- The mortar mix should be workable- easily transported to the place of application.
- It should develop adequate strength in tension, compression and bond for the work for it is used.
- It should capable of retaining sufficient water during its application.
- It should be sufficiently plastic easily placed on the bed is construction in the form of thin, smooth and uniform layer.
- It should be durable and strong in itself on drying and hardening at the same time. It should not react in anyway with construction units.
- It should set and garden quickly construction could be done with speed.
- It should not develop any cracks on drying and should be able to maintain their appearance for quite long period.
- It should capable of developing the designed stresses.
- It should be economical to make without compromising on any of the qualities.

Types of Mortar

1. Cement mortars
2. Lime mortars
3. Surki Mortars
4. Ganged Mortars
5. Mud mortars

Cement Mortars

Cement Mortars is a homogeneous pate of cement, sand, and water. Different cement mortars are obtained by mixing different proportions of cement and sand. To prepare cement mortars, cement and sand are properly mixed in dry conditions. Water is then added gradually and mixed using a hovel The water sho be free from clay and other impurities. To safety, strength, and durability of the resulting wall or any structure depend upon the quality of mortars used as a binding medium.

- For Plaster in on walls and slabs, to make them impervious.
- To fill cracks and joints in the wall
- For pointing the joints of the masonry.
- For preparing the building blocks.

Lime mortars

Lime mortar is a type of mortar where lime is used as binding material and sand is used as fine aggregate. There are two types of limes namely fat lime and hydraulic lime. Fat lime in lime mortars requires 2 to 3 times of sand and its uses for dry work. The lime mortars have plasticity so they can place easily. The pyramids at Giza plastered with lime mortars.

Gauged mortars

Ganged mortar is economical than cement concrete. Cement and lime both use as binding material and sand uses as fine aggregate. It is a lime mortar where cement adds to gain higher strength. The process of known as gauging. The cement to the lime proportion varies from 1:6 to 1:9.

Surkhi Mortars

Lime uses as binder material and surkhi is employed as fine aggregate. The surkhi is finely-powdered burnt clay which provides more strength than sand and cheaply.

Mud mortars

Mud mortar is a type of mortar. They use as binding material and sawdust, rice husk, or cow-dung is used as fine aggregate. Mud mortars are useful where lime or cement is not available.

Uses of mortar

Different mortars use for different purposes in civil engineering constructions owing to their plasticity, workability, binding, and setting properties.

- It uses to distribute in uniform load over the lower bricks.
- Mortars used to form soft layers from bricks and stones in masonry work.
- It also used to bind the bricks and stones with each other.
- It also provides water lightness against the weather.

- Mortars use as the plaster or impermeable covering for walls and roofs.
- For various types of painting work to protect the joints of bricks.
- It uses to hide the open joints of brickwork and stonework.
- Mortars use to repair cracks of any structure.
- It uses to improve the general appearance of the structure.
- It also uses for various ornamental works to improve the general appearance of a building or structure.

Tests on mortar

- Flow test
- Compressive strength test
- Air content test
- Setting time test

Flow Test

The mortars flow test utilizes a specially designed table that repeatedly raises and drops a known quantity of mortar times. During the test, the mortar will spread or flow to from a circular mass and the diameter of the mass measures and compared to the initial size. The increase in size express as a percentage of the initial size:

For most mortars, the required flow is 110%. The flow test repeated, using a fresh batch of mortars each time until the desired flow achieves. The quantity of water needs to achieve flow record, and this mortar then tests for compressive strength.

Compressive strength Test

This is probably the most relevant test to evaluate the performance of fly ash since concrete value mainly for its high compressive strength, and the pozzolanic withing the concrete produced additional cement and thus higher strengths. Once the proper flow achieved, the mortar places and compacted into bronze cube-shaped molds. The surface of each cube finish using a trowel, and the molds placed into a moist curing cabinet.

After 24 hours of curing, the molds stripe from the cube specimens. The compressive strength then tests at specified curing intervals, usually 1 or 3 days, 7 days, 28 days, and 56 days.

Air Content test

Mortar prepares using a similar method as for compressive strength, except that coarser sand uses and an AEA mix with mortars to centenarian air within the mix. After mixing, the flow of the mortar determines. If the flow is within the specified range, then a portion of the mortar places and compacted into a brass cup of known volume, and the mass of the cup mortars determined.

Subtracting the mass of the cup, and knowing the density of each component, the air content of the mortars calculate. The test result report is the quantity o AEA requires to achieve a mortar air content of 18%.

Setting Time test

The elapsed time after mixing whereupon the mortar begins to harden is the set time. This test is most commonly performed on cement paste but can conduct using mortar. The test completed by measuring the penetration of a steel needle into the paste or mortar over the course of several hours. The needle is part of an instrument called a "Vicat apparatus".When the penetration of the needle into the material is less than 25mm for paste or 10 mm for mortar, the material has achieved its "initial set". The time requires to achieve this degree of hardening reported as the test result.

Special Purpose Mortars

1. Fire Resistant Mortar
When there are fire warnings or similar dangers to a building structure in a particular zone, then fire resistant mortar is used as these acts as a fireproofing shield. Mortar attains fire resistance properties when aluminous cement is added to the fine powder of fire bricks.

2. Packing Mortar
The main ingredients of packing mortars are normally cement-loam, cement-sand or sometimes even cement-sand-loam. This kind of mortar is commonly used in the packing of oil wells. Packing mortar needs to be high homogeneity and strength, and also should be resistant to water.

3. Sound Absorbing Mortar
Just as the name suggests, this kind of mortar helps in reducing noise levels by acting as a soundproofing layer. The mortar mixture contains cement, lime, slag, gypsum, etc. as binding materials and cinders and pumice as adulterants.

4. Chemical Resistant Mortar
This type of mortar is suitable for those structures which are more prone to chemical attacks. Such mortar contains additives which can fight chemical attack. Typically, there are many different types of chemical resistant mortars which can be prepared but eventually, the selection of mortar is largely dependent on expected damage by a particular chemical or group of chemicals.

5. Lightweight Mortar
Generally used in heat-proof and soundproof constructions. This kind of mortar is obtained by adding wood powder, sawdust, or, jute fibers coir, asbestos fibers, etc. to the cement or lime mortar.

6. X-ray Shielding Mortar
To offer protection against the ill effects of the X-ray machines, the walls and ceilings of the X-ray rooms are plastered by X-ray shielding mortar. This is a very heavy mortar which has a

bulk density of around 22KN/m3. To prepare this special mortar, fine aggregates from heavy rock and suitable admixtures are used.

When working with brick and other masonry units, it is very important that one uses the right type of mortar for the masonry. This is because few mortars are too hard for some types of masonry and it can further lead to cracks in the structure and reduce the strength of the structure.

Plain Concrete:

Plain cement concrete is the mixture of cement, fine aggregate(sand) and coarse aggregate without steel. PCC is an important component of a building which is laid on the soil surface to avoid direct contact of reinforcement of concrete with soil and water.

Material Used in Plain Cement Concrete

The general specifications of materials used in PCC are -

1. Coarse Aggregate

Coarse aggregate used in the PCC must be of hard broken stone of granite or similar stone, free from dust, dirt and other foreign matter. The stone ballast shall be 20 mm in size and smaller. All the coarse material should be retained in a 5mm square mesh and should be well graded so that the voids do not exceed 42%.

2. Fine Aggregate

Fine aggregate shall be of coarse sand consisting of hard, sharp and angular grains and shall pass through a screen of 5 mm square mesh. Sand shall be of standard specifications, clean and free from dust, dirt and organic matter. Sea sand shall not be used.

3. Cement

Portland Pozzolana cement (P.P.C) is normally used for plain cement concrete. It should conform to the specifications and shall have the required tensile and compressive stresses and fineness.

4. Water

Water used shall be clean and reasonably free from injurious quantities of deleterious materials such as oils, acids, alkalis, salts and vegetable growth. Generally, potable water shall be used having a pH value not less than 6. The maximum permissible limits for solids shall be as per IS 456:2000 Clause 5.4, Page No 15.

Advantages of Laying Plain Cement Concrete

- Required cover to bottom reinforcement is ensured, as cover blocks rest on a firm PCC.
- The effective depth of RCC members is achieved as the formworks can be easily, uniformly and sturdily fixed, resulting in better dimension accuracy of foundation RCC member.
- Reinforcement steel bars placed on PCC, are never in touch with the ground soil, which may be chemically active and may lead to steel corrosion in the immediate future.
- Ease in the placement of steel cages and increased productivity.

- Concrete does not bond with ground soil (clay); PCC acts as a barrier to soil and bond well to overlayed structural grade concrete.

Reinforced cement concrete

Reinforced cement concrete is a combination of concrete and steel bars (reinforcement bars) where they carry the compressive force and tension of a structure simultaneously.

As we know that concrete is very strong in compression but weak in tension and its resistance to tension is also low. That's why plain concrete can be used only where the member is in pure compression, but on the other hand, steel is equally strong in compression and tension.

So the combination of steel and concrete works very well and they are used to take up all the stresses. Such a combination of steel and concrete is called reinforcement cement concrete.

Advantages Of Reinforced Cement Concrete:

1. Reinforced concrete has high compressive strength.

2. It is economical in ultimate cost.

3. It can be produced easily at the construction site.

4. Reinforced concrete has monolithic characters which gives much rigidity to the structure.

5. It is durable, fire-resistant, and almost impermeable to moisture.

6. The materials used in reinforced concrete are easily obtainable.

7. Maintenance cost of the reinforced concrete structure is almost ignorable.

8. Due to the flexibility and fluidity nature, reinforced concrete can be moulded into any desired shape.

9. It is the most useful and economical material in constructions such as footings, piers, damp, etc.

Prestressed concrete

Pre-stressed concrete is a form of concrete where initial compression is given in the concrete before applying the external load so that stress from external loads is counteracted in the desired way during the service period. This initial compression is introduced by high-strength steel wire or alloys (called 'tendons') located in the concrete section.

Methods of Prestressing: The prestressing can be performed by two methods:

- Pre-tensioning
- Post-Tensioning

- Pre-tensioning

In the pre-tensioning method, the stress is induced by initially tensioning the steel tendons. These are wires or strands that are tensioned between the end anchorages. After this tensioning process, the concrete casting is performed. Once the casted concrete has hardened sufficiently, the end anchorages arranged are released. This releasing transfers the prestress force to the concrete. The bond between the concrete and the steel tendons facilitates this stress transfer. As shown in figure-2, the tendons that are protruding at the ends are cut and a finished look is achieved. In order to induce prestress force in the pre-tensioning method, a large number of tendons and wires are used. This arrangement hence demands a large area of surface contact to make the bond and stress transfer possible.

- Post Tensioning

The procedure in post-tensioning is depicted in the figure-3 below. Here, the steel is prestressed only after the beam is cast, cured and attain strength to take the prestress. Within the sheathing, the concrete is cast. For the passage of steel cables, ducts are formed in the concrete.

Advantages:

The major advantages of Prestressed Concrete are:

- The prestressing of concrete by using high tensile steel improve the efficiency of the materials
- The prestressing system works for a span greater than 35m.
- Prestressing enhances shear strength and fatigue resistance of concrete
- Dense concrete is provided by prestressing systems thus improving the durability
- Best choice for the construction of sleek and slender structures.
- Prestressing helps to reduce the dead load of the concrete structure
- Prestressed concrete remains uncracked even at service load conditions which proves the structural efficiency
- Composite construction by using the prestressed concrete unit and cast-in-unit derives the economical structure

Disadvantages of Prestressed Concrete

- Higher material costs
- Prestressing is an added cost
- Formwork is more complex than for RC (flanged sections, thin webs) – thus, precast not as ductile as RC

Steel: Steel is one of the most important building materials used in construction. Steel is the backbone of a structure. The strength and durability of a structure significantly depend upon the steel used. With technological advancement, various types of steel have been introduced like mild steel, TMT, steel, alloy steel, etc.

Structural steel

Structural Steel is a special kind of Steel. It is used for construction purposes. Due to its rigidity and high strength-to-weight ratio, structural Steel is mainly employed in buildings. Structural Steel is used in houses, warehouses, airplane hangars, educational facilities, bridges, stadiums, etc.

Structural Steel is Steel that contains carbon, not more than 2.1%. These are also called Carbon Steel, and structural Steel typically has a carbon content of less than 0.6%.

Properties of structural steel:

- Density: The density of Structural Steel is 7750 to 8100 kg/m3.
- Young's Modulus of Elasticity: Typical values for structural steel range from 190-210 GPa
- Poisson's ratio: For structural Steel, the acceptable value ranges from 0.27 to 0.3.
- Tensile strength: Structural Steel has high tensile strength, so it is preferred over other construction materials.
- Yield strength: The yield strength, also known as the yield point, is the stress at which an object permanently deforms. When stress is removed, it does not revert to its former shape. Carbon structural steel has a yield strength ranging from 187 to 758 MPa. The values of structural Steel constructed of alloys range from 366 to 1793 MPa.
- Shear strength: The shear strength of steel structure is specified at the failure under shear stress, and it is about 0.57 times the yield stress of structural Steel.
- Hardness: The resistance of an object to shape change when force is applied is referred to as hardness. There are three different types of hardness tests. Scratch, indentation, and rebound are all terms used to describe the process of scratching and indenting, and the hardness of structural Steel manufactured with alloys ranges from 149 to 627 kg. Carbon structural steels have a weight range of 86 to 388 kg.
- Melting point: Because there are so many different types of structural Steel, there is no standard melting point.
- Specific heat: The amount required to raise an object's temperature by a particular quantity is known as specific heat or heat capacity. A higher specific heat value indicates that the thing is more insulating. The units of measurement are Joules per Kilogram Kelvin. Specific heat for carbon structural steel ranges from 450 to 2081 J/kg-K, while for structural alloy steel, it ranges from 452 to 1499 J/kg-K.

Types of Steel Sections

Structural steel members are fabricated in factories according to their intended use. Continuous casting molds are used to cast rolled steel parts with no joints. The following sections describe the various shapes and forms of rolled steel sections.

Rolled Steel I-sections (Beam sections).

Rolled Steel Channel Sections.

Rolled Steel Tee Sections.

Rolled Steel Angles Sections.

Rolled Steel Bars.

Rolled Steel Tubes.

Rolled Steel Flats.

Rolled Steel Sheets

Composition of Structural Steel

The chemical compositions influence the properties of Structural Steel. Some chemical elements used to enhance the mechanical properties are listed below. Structural Steel is a mixture of iron and other metals. Some parts are purposefully added to iron to achieve specific properties and features; the various compositions have been discussed in the following:

Carbon: One of the most significant chemical ingredients in Steel is carbon. Carbon concentration rises, resulting in a material with less flexibility and more strength.

Chromium: Small levels of chromium are present, combined with copper and nickel, to strengthen the material's corrosion resistance.

Manganese: Manganese, along with oxygen and sulphur, is employed as a neutralizer in the hot rolling of Steel, and it has effects on the material properties of steel grades that are similar to those of carbon.

Aluminum: Aluminum is a key deoxidizer that contributes to forming a finer-grained crystalline microstructure.

Copper: Copper is used to promoting corrosion resistance.

Sulphur and phosphorus: Sulphur and phosphorus are often limited in steel alloys because they negatively impact the Steel's durability and strength.

Molybdenum: Molybdenum increases the Steel's strength at high temperatures and its corrosion resistance.

Construction Chemicals:

Construction chemicals have always been playing important roles in virtually all sorts of construction projects, be it industrial projects, residential building projects, commercial building projects and so on. These chemicals are often used in various elements of projects in order to achieve various important qualities such as workability, durability etc. Construction chemicals exist in many varieties from a large number of manufacturers worldwide.

Concrete curing compounds

Concrete curing compound consists essentially of waxes, natural and synthetic resins, and solvents of high volatility at atmospheric temperatures. The compound forms a moisture retentive film shortly after being applied on a fresh concrete surface. White or gray pigments are often incorporated to provide heat reflectance, and to make the compound visible on the structure for inspection purposes. Curing compound should not be used on surfaces that are to receive additional concrete, paint, or tile which require a positive bond, unless it has been demonstrated that the membrane can be satisfactorily removed before the subsequent application is made, or that the membrane can serve satisfactorily as a base for the later application.

Polymer bonding agents

Polymer Bonding Agent is an aqueous emulsion of a polymer and chemical admixtures. It is designed for use as a bonding agent with concrete and cement-based products in interior or

exterior applications. Polymer Bonding Agent is also designed for use as a polymer modifier in mortars and concretes to develop increased tensile, flexural and bond strengths. The use of Polymer Bonding Agent in concrete and shotcrete also gives significant improvements in resistance to penetration by chlorides and de-icing salts.

Mould releasing agents

Mould release agents come in handy when you have materials that are shaped and constructed in moulds. Without the releasing agent, your mould may become damaged or even break when it is time to remove it. Mould release agents come in a variety of textures with the most commonly used one being an oil type base. If you have never used a releasing agent before, it is similar to placing oil or butter in the bottom of a dish to remove your final baking product. Below, you will find the three most commonly used types and their purpose in the manufacturing industry.

Form release agents

These compounds are applied on the inner surfaces of forms, not only facilitate stripping of formwork but also render concrete surfaces smoother. They also help enhance the life-span of the forms. Form releasing agents can be oil based, resin based, water based, organic chemical based etc.

Protective and decorative coatings

A protective coating is a layer of material applied to the surface of another material with the intent of inhibiting or preventing corrosion. A protective coating may be metallic or non-metallic. Protective coatings are applied using a variety of methods, and can be used for many other purposes besides corrosion prevention. Commonly used materials in non-metallic protective coatings include polymers, epoxies and polyurethanes. Materials used for metallic protective coatings include zinc, aluminum and chromium. Special materials are used in the finishing coats of plastering or over the plastered surfaces to meet one or more of specific requirements such as decorative appearance, high durability,fire – proofing,heat insulation,sound insulation,early completion,high strength etc..

Concrete floor hardeners

These are chemicals added in floor concrete in order to render it denser and more durable. They also usually enhance chemical resistance, impact & abrasion resistance, waterproofing capability etc. besides reducing dusting. All these are required attributes especially for industrial, commercial or factory floors. Ultimately good quality floor hardeners reduce repairs and maintenance of concrete floors drastically besides making them long lasting thus adding to cost effectiveness as well. Floor hardeners can be liquid or solid, metallic or nonmetallic. Metallic floor hardeners (solid) are well graded ferrous aggregates. Liquid floor hardeners are water, silicate etc. based solutions. Pigmented floor hardeners also improve the appearance of floor surfaces. Floor hardeners are usually applied as per manufacturer's specifications This construction chemical Improves the abrasion resistance of dusty or poorly cured concrete by up to 3 times. Has good resistance to alkali solution and petroleum solvents but poor resistance to strong acids.

Epoxy coatings

These can come as water or oil-based solutions or as solvent-free. They can be single or two-component. Single-component epoxy paints are usually oil based. Two-component epoxy coatings are mixed in situ in proportions as prescribed by their manufacturers and they are quite suitable for factory, industrial or commercial building applications by dint of their excellent chemical & thermal resistant characteristics, hardness, durability, waterproofing

characteristics etc. They are solvent-free. Epoxy coatings are also used in flooring for decorative purposes.

UNIT 2- CIVIL ENGINEERING- SOCIETAL AND GLOBAL IMPACT

Infrastructure - Habitats, Megacities, Smart Cities, futuristic visions; Current and Futuristic transportation systems. Civil Engineering Projects & Socio-economic developments

INFRASTRUCTURE

Infrastructure is the set of fundamental facilities and systems that support the sustainable functionality of households and firms. Infrastructure is composed of public and private physical structures such as roads, railways, bridges, tunnels, water supply, sewers, electrical grids, and telecommunications (including Internet connectivity and broadband access).

Types of Infrastructure

Soft Infrastructure

Soft infrastructures are the institutions that make up an economy, like healthcare systems, law enforcement, financial institutions and educational systems.

Hard Infrastructure

Hard infrastructures are the physical systems that help run a region or nation such as roads, bridges and telecommunications.

Sustainable Infrastructure

The concept of sustainable infrastructure refers to equipment and systems that are designed tomeet the population's essential service needs — including roads, bridges, telephone **,** hydroelectric power stations, etc. — based on all-round sustainable principles.

Role of Civil Engineering in Sustainable Infrastructure/ development

The American Society of Civil Engineers (ASCE) defines sustainability as a set of economic, environmental, and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or the availability of economic, environmental, and social resources. Sustainable development is the application of these resources to enhance the safety, welfare, and quality of life for all of society.

Civil engineer shall be committed to the following ASCE Principles of Sustainable Development/Infrastructure:

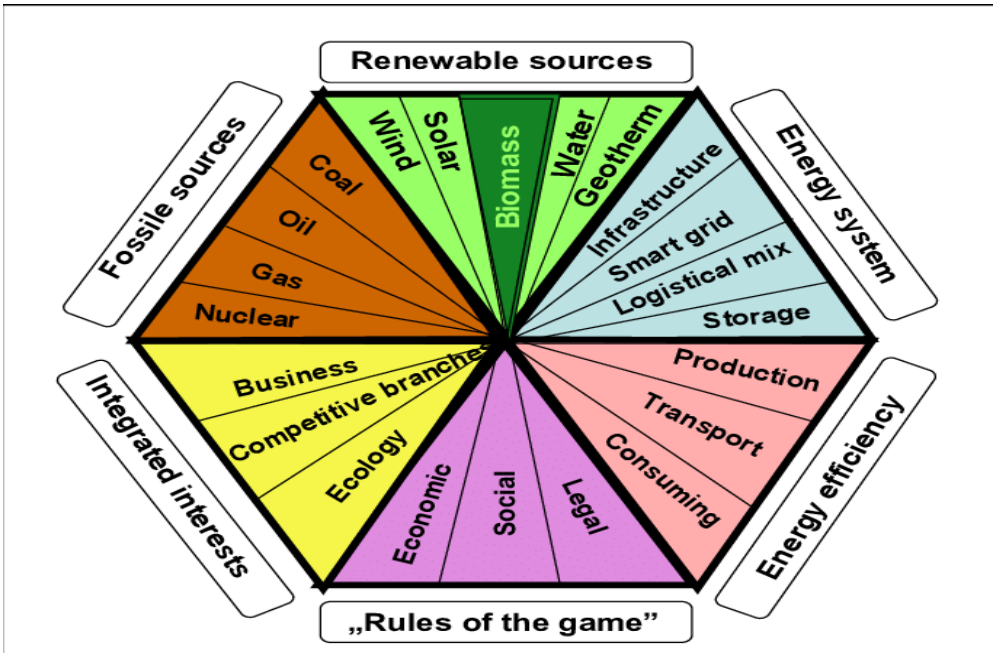
UNIT 2- CIVIL ENGINEERING- SOCIETAL AND GLOBAL IMPACT

- **Principle 1- Do the Right Project**. A proposed project's economic, environmental, and social effects on each of the communities served and affected must be assessed and understood by all stakeholders before there is a decision to proceed with a project. Consider non-structural as well as structural (built) solutions to the needs being addressed; and
- **Principle 2 - Do the Project Right**. The civil engineer shall actively engage stakeholders and secure public understanding and acceptance of a projects economic, environmental, and social costs and benefits. To move toward conditions of sustainability, engineers must design and deliver projects that address sustainability holistically (from concept to demolition or reuse) rather than adding a variety of "green" features onto a conventional project.

Sustainable Infrastructure to be Developed by Civil Engineers

- **Sustainable Energy**

Energy is sustainable if it "meets the needs of the present without compromising the ability of future generations to meet their own needs".



- **Sustainable Water**

Sustainable water management means using water in a way that meets current, ecological, social, and economic needs without compromising the ability to meet those needs in the future.

UNIT 2- CIVIL ENGINEERING- SOCIETAL AND GLOBAL IMPACT

Figure 1. The SWM Profile's Conceptual Path Toward Sustainable Water Management

It requires water engineers to look beyond jurisdictional boundaries and their immediate supply operations, managing water collaboratively while seeking resilient regional solutions that minimize risks.

- **Sustainable Waste Management**

Sustainable waste management is "using material resources efficiently to cut down on the amount of waste produced, and where waste is generated, dealing with it in a way that actively contributes to the economic, social, and environmental goals of sustainable development.

The FIVE R's in sustainable waste management are as follows

1. Reduce
2. Reuse
3. Repair
4. Rot
5. Recycle

- **Sustainable Transportation**

It is the transportation system that has the intermodal network of well designed, maintained and interconnected highways, railways, inland waterways, sea ports, river ports, airports or dry ports, through modal shift.

The Sustainable transport system should be developed by the following principles.

1. Optimizes the needs of transporting goods and passengers

2. Minimizes consumption of energy, land and other resources
3. Generates low emissions of, greenhouse gases and ozone depleting substances
4. Minimizes the adverse social impacts arising from transport operations.

- **Sustainable Materials**

Sustainable construction means using renewable and recyclable materials when building new structures, as well as reducing energy consumption and waste. The primary goal of sustainable construction is to reduce the industry's impact on the environment.

Sustainable materials in civil engineering.

1. Bamboo
2. Recycled Plastic
3. Reclaimed or Recycled Steel
4. Plant-based Polyurethane Rigid Foam
5. Fly ash
6. Reclaimed Aggregates, etc

HABITATS

A habitat (which is Latin for "it inhabits") is an ecological or environmental area that is inhabited by a particular species of animal, plant or other type of organism.

MEGA CITIES

A megacity is, according to the definition of the United Nations, a city with more than 10 million inhabitants.

Problems arising from megacities

- Slums
- Traffic congestion
- Urban sprawl
- Air pollution
- Energy and material resources

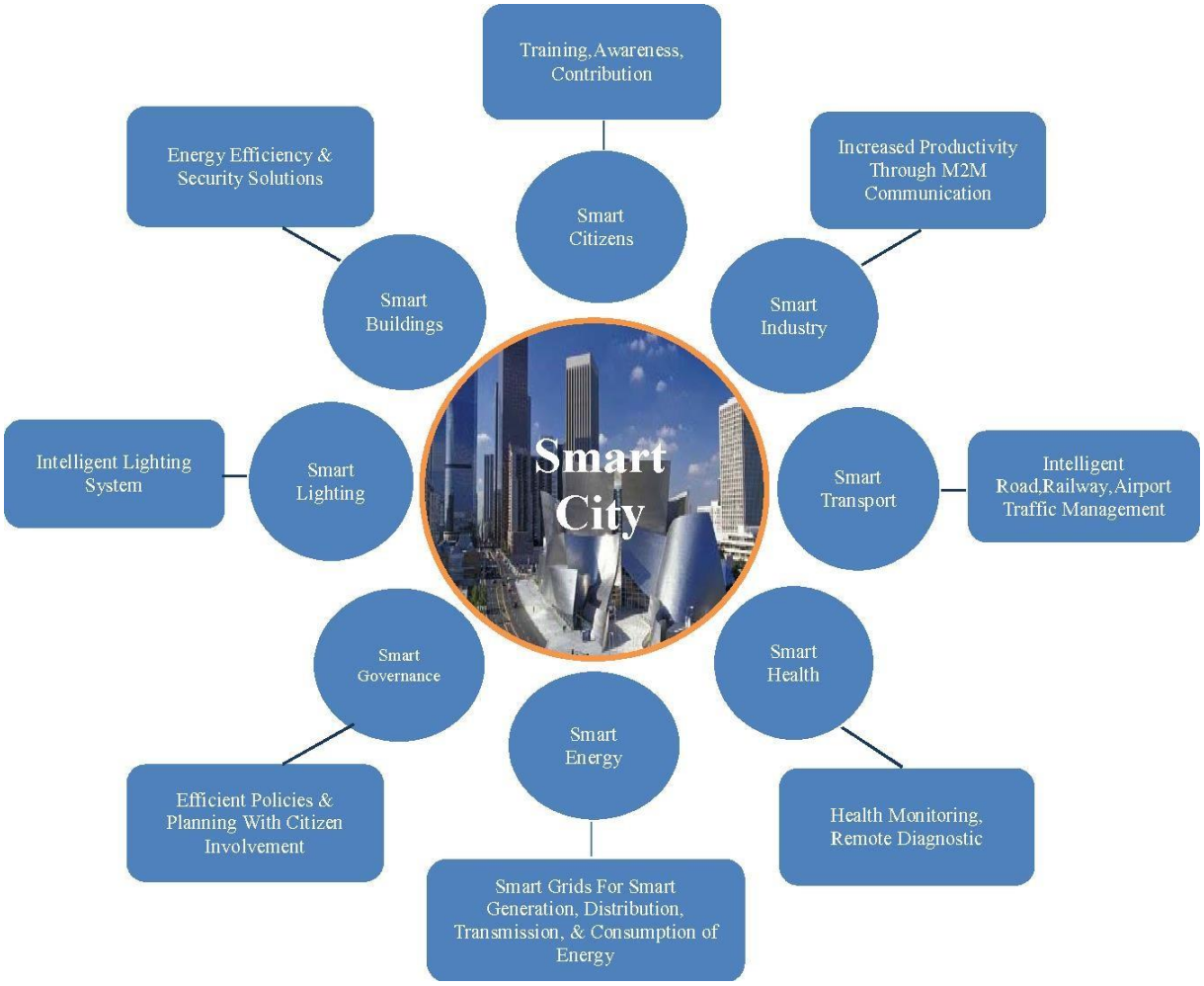
Innovation in solving problems:

- Reduce the carbon footprint
- Create mechanisms aimed at listening to the inhabitants
- Create fresh urban islands-tree cover.
- Install green roofs
- Promote city agriculture, .

- Implement Internet of Things (IoT) applications
- Use of eco-efficient technologies.
- Develop an intelligent public transport system

SMART CITY

A smart city is a technologically modern urban area that uses different types of electronic methods, voice activation methods and sensors to collect specific data. Information gained from that data are used to manage assets, resources and services efficiently; in return, that data is used to improve the operations across the city.



The development of smart city can be effective if the following principles are followed:

1. Define exactly what is the community
2. Study the Community
3. Develop a smart city Policy
4. Engage The Citizens

UNIT 2- CIVIL ENGINEERING- SOCIETAL AND GLOBAL IMPACT

People Processes and Technology (PPT) in Smart Cities

People:

The concept of smart cities hinges on the active involvement of people inspired to use information technology. The smart cities should be people-focused, leaders desiring to make their cities smarter need to concentrate on attracting people who can help them create user-friendly, sustainable, efficient, aesthetically pleasing, and liveable environments.

Processes:

Smart cities reach their full potential when citizens, services, systems, and organizations are connected in order to make cities more liveable and efficient. The cities with better communication, energy, safety, security, water & sanitation services, and transportation function seamlessly, can cities offer their citizens a better quality of life and a flourishing economy. Cognitive computing systems are now available that can collect, integrate, and analyse data from throughout the city and help make senseof it all. A cognitive computing system is like the brain orchestrating how the parts of the body work together. The central nervous system of the smart city is going to be the Internet of Things (IoT).

Technology

Technology offer newfound promise for the future of cities, more efficient resource usage, greater connectivity between people and places, and broader opportunity for all. They also promise a competitive and sustainable edge relative to other cities slow to adapt. The most important technologies are going to be broadband, cloud, cognitive computing, and the Internet of Things.

FRAMEWORKS IN SMART CITIES

1. Technology framework
2. Human framework
3. Institutional framework
4. Energy framework
5. Data Management framework

SMART CITY IMPLEMENTATION IN INDIA

The purpose of the Smart Cities Mission is to drive economic growth and improve the quality of life of people by enabling local area development and harnessing technology, especially technology that leads to Smart outcomes.

Core infrastructure elements in a Smart City

1. Adequate water supply

2. Assured electricity supply
3. Sanitation, including solid waste management
4. Efficient urban mobility and public transport
5. Affordable housing, especially for the poor
6. Robust IT connectivity and digitalization
7. Good governance, especially e-Governance and citizen participation
8. Sustainable environment
9. Safety and security of citizens, particularly women, children and the elderly
10. Health and education.

CURRENT AND FUTURISTIC TRANSPORTATION SYSTEMS

Current Transportation Systems in India

The various modes of transportation used in India are as follows:

1. Road

The various classes of road presently used in India are Expressways, National highways, State highways, Major district roads, other district roads and village roads.

The various modes of vehicles used in roadway are as follows:

- Two wheelers
- Light Motor vehicles: Car
- Heavy motor vehicle: Truck

2. Railways

The railway network travels across the country, covering more than 7,321 stations over a total route length of more than 67,415 km and track length of about 123,542 km as of March 2021.

The various railway transport in India are as follows:

A) Commuter rail transport

1. Suburban rail
2. Mass rapid transit system
3. Metro
4. Monorail
5. Tram
6. International links

B) Freight and Long Distance haulage rail Transport

1. Passenger Trains
2. Freight Trains
3. Express Trains

3. Waterways

India is endowed with an extensive network of waterways in the form of rivers, canals, backwaters, creeks and a long coastline accessible through the seas and oceans. It has the largest carrying capacity of any form of transport and is most suitable for carrying bulky goods over long distances.

The various waterway transport in India are as follows:

A) Inland Canal & Waterways

India has an extensive network of inland waterways in the formof rivers, canals, backwaters and creeks. The total navigable length is 14,500 km out of which about 5,200 km of river and 4,000 km of canal can be used by mechanized crafts.

B) Coastal Waterways

The country has a coastline of nearly 7,517 km. India has the largest merchant shipping fleet among developing countries. The country has a total of 14 major, 187 notified minor and intermediate ports.

4. Airways

India had the world's third-largest civil aviation market in 2017, with the number of passengers growing at an average annual rate of 16.3% between 2000 and 2015. There are 346 civilian airfields in India – 253 with paved runways and 93 with unpaved runways. The airports in India are used for Military and civil aviation purposes. There are 45 heliports in India. India also has the world's highest helipad at the Siachen Glacier at a height of 6400 m above mean sea level.

5. Pipelines

Pipeline transportation is a method of transportation which involves movement of solid, liquid or gaseous products over long distances through pipelines. The length of pipeline network in India are as follows:

1. Length of pipelines for crude oil is 20,000 km.
2. Length of Petroleum products pipeline is 15,000 kilometres.

Futuristic Transportation Systems in India

UNIT 2- CIVIL ENGINEERING- SOCIETAL AND GLOBAL IMPACT

The modern technological-driven innovative system will help the people 'to stay anywhere', 'to work from anywhere', and 'to go to anywhere' from their native place with very much ease in the upcoming future. The various futuristic transport infrastructure systems in development stage for India are as follows:

1. **Hyperloop**

Hyperloop consists of gas steel tubes that transport pods to transport the passengers from one point of place to any different place, all at a supersonic speed. Proposals are made for various Hyperloop corridor developments in INDIA.

2. **Bullet Train**

National High Speed Rail Corporation launches the first **bullet train in India** running between Mumbai to Ahmedabad.

3. **High-speed rail(HSR)**

High-speed rail (HSR) in India is currently under construction and the country does not have high-speed rail corridors, or lines operating at 200 km/h (120 mph) or above currently under UIC definition. The fastest train of India is Vande Bharat Express with a top speed of 180 km/h which it attained during a trial run, while the fastest operating train isthe Gatimaan Express with a top operating speed of 160 km/h.

The first high-speed railway corridor of length 508 km is currently under construction between Mumbai and Ahmedabad at a top operational speed of 320 km/h (200 mph) along the western coast. The corridor will use Standard gauge line and will be built with Shinkansen technology.

4. **Bharat Mala**

The Bharatmala Pariyojana (lit. 'India garland project') is a centrally-sponsored and funded Road and Highways project of the Government of India. The total investment for 83,677 km committed new highways is estimated at ₹5.35 lakh crore making it the single largest outlay for a government road construction scheme.

5. **Sagarmala**

The **Sagarmala Programme** (transl. garland of the sea) is an initiative by the government of India to enhance the performance of the country's logistics sector. The programme envisages unlocking the potential of waterways and the coastline to minimize infrastructural investments required to meet these targets.It entails investing ₹8.5 trillion to

set up new mega ports, modernizing India's existing ports, developing of 14 Coastal Economic Zones (CEZs) and Coastal Economic Units, enhancing port connectivity via road, rail, multi-modal logistics parks, pipelines & waterways and promoting coastal community development, with the aim of boosting merchandise exports by US$110 billion and generating around 10 million direct and indirect jobs.

Other Infrastructure Works:

1. Charging Infrastructure
2. Autonomous vehicle systems

Civil Engineering Projects & Socio-economic developments

- General civil engineering is concerned with the overall interface of fixed projects with the greater world.
- Civil engineers work closely with surveyors and specialized civil engineers to fit and serve fixed projects within their given site, community and terrain by designing grading, drainage (flood control), paving, water supply, sewer service, electric and communications supply and land (real property) divisions. General engineers spend much of their time visiting project sites, developing community/neighbourhood consensus, and preparing construction plans.
- Civil engineering systems is a discipline that promotes the use of systems thinking to manage complexity and change in civil engineering within its wider public context.
- The proper development of civil engineering infrastructure requires a holistic, coherent understanding of the relationships between all of the important factors that contribute to successful projects while at the same time emphasizing the importance of attention to technical detail.
- Its purpose is to help integrate the entire civil engineering project life cycle from conception, through planning, designing, making, operating to decommissioning.

Coastal engineering

Concerned with managing coastal areas. In some jurisdictions, the terms sea defence and coastal protection mean defence against flooding and erosion, respectively. The term coastal defence is the more traditional term, but coastal management has become more popular as the field has expanded to techniques that allow erosion to claim land.

Construction engineering

Involves planning and execution, transportation of materials, site development based on hydraulic, environmental, structural and geotechnical engineering. As construction firms tend to have higher business risk than other types of civil engineering firms do, construction engineers often engage in more business-like transactions, for example, drafting and reviewing contracts, evaluating logistical operations, and monitoring prices of supplies.

Earthquake engineering

Involves designing structures to withstand hazardous earthquake exposures. Earthquake engineering is a sub-discipline of structural engineering. The main objectives of earthquake engineering are[24] to

understand interaction of structures on the shaky ground; foresee the consequences of possible earthquakes; and design, construct and maintain structures to perform at earthquake in compliance with building codes.

Environmental engineering

The contemporary term for sanitary engineering, though sanitary engineering traditionally had not included much of the hazardous waste management and environmental remediation work covered by environmental engineering. Public health engineering and environmental health engineering areother terms being used.

Environmental engineering deals with treatment of chemical, biological, or thermal wastes, purification of water and air, and remediation of contaminated sites after waste disposal or accidental contamination. Among the topics covered by environmental engineering are pollutant transport, water purification, waste water treatment, air pollution, solid waste treatment, recycling, and hazardous waste management. Environmental engineers administer pollution reduction, green engineering, and industrial ecology. Environmental engineers also compile information on environmental consequences of proposed actions.

Forensic engineering

The investigation of materials, products, structures or components that fail or do not operate or function as intended, causing personal injury or damage to property. The consequences of failure are dealt with by the law of product liability. The field also deals with retracing processes and procedures leading to accidents in operation of vehicles or machinery. The subject is applied most commonly in civil law cases, although it may be of use in criminal law cases. Generally, the purpose of a Forensic engineering investigation is to locate cause or causes of failure with a view to improve performance or life of a component, or to assist a court in determining the facts of an accident. It can also involve investigation of intellectual property claims, especially patents.

Geotechnical engineering

The study of rock and soil supporting civil engineering systems. Knowledge from the field of soil science, materials science, mechanics, and hydraulics is applied to safely and economicallydesign foundations, retaining walls, and other structures. Environmental efforts to protect groundwater and safely maintain landfills have spawned a new area of research called geo-environmental engineering.[25][26]

Identification of soil properties presents challenges to geotechnical engineers. Boundary conditions are often well defined in other branches of civil engineering, but unlike steel or concrete, the material properties and behaviour of soil are difficult to predict due to its variability andlimitation on investigation. Furthermore, soil exhibits nonlinear (stress-dependent) strength, stiffness,and dilatancy (volume change associated with application of shear stress), making studying soil mechanics all the more difficult.[25] Geotechnical engineers frequently work with professional geologists and soil scientists.[27]

Materials science

Closely related to civil engineering. It studies fundamental characteristics of materials, and deals with ceramics such as concrete and mix asphalt concrete, strong metals such as aluminium and steel, and thermosetting polymers including polymethylmethacrylate (PMMA) and carbon fibres.

Materials engineering

Involves protection and prevention (paints and finishes). Alloying combines two types of metals to produce another metal with desired properties. It incorporates elements of applied physics and chemistry. With recent media attention on nanoscience and nanotechnology, materials engineering has been at the forefront of academic research. It is also an important part of forensic engineering and failure analysis.

Structural engineering

Concerned with the structural design and structural analysis of buildings,bridges, towers, flyovers (overpasses), tunnels, off shore structures like oil and gas fields in thesea, aerostructure and other structures. This involves identifying the loads which act upon a structure and the forces and stresses which arise within that structure due to those loads, and then designingthe structure to successfully support and resist those loads. The loads can be self-weight of the structures, other dead load, live loads, moving (wheel) load, wind load, earthquake load, load from temperature change etc. The structural engineer must design structures to be safe for their users andto successfully fulfill the function they are designed for (to be *serviceable*). Due to the nature ofsome loading conditions, sub-disciplines within structural engineering have emerged, including windengineering and earthquake engineering.[29]

Design considerations will include strength, stiffness, and stability of the structure when subjected to loads which may be static, such as furniture or self-weight, or dynamic, such as wind, seismic, crowd or vehicle loads, or transitory, such as temporary construction loads or impact. Other considerations include cost, constructability, safety, aesthetics and sustainability.

Surveying

The process by which a surveyor measures certain dimensions that occur on or near the surface of the Earth. Surveying equipment such as levels and theodolites are used for accurate measurement of angular deviation, horizontal, vertical and slope distances. With computerisation, electronic distance measurement (EDM), total stations, GPS surveying and laser scanning have to a large extent supplanted traditional instruments. Data collected by survey measurement is converted into a graphical representation of the Earth's surface in the form of a map. This information is then used by civil engineers, contractors and realtors to design from, build on, and trade, respectively. Elements ofa structure must be sized and positioned in relation to each other and to site boundaries and adjacent structures.

Although surveying is a distinct profession with separate qualifications and licensing arrangements, civil engineers are trained in the basics of surveying and mapping, as well as geographic information systems. Surveyors also lay out the routes of railways, tramway tracks, highways, roads, pipelines and streets as well as position other infrastructure, such as harbours, before construction.

Land surveying

Land surveyors are not considered to be engineers, and have their own professional associations and licensing requirements. The services of a licensed land surveyor are generally required for boundary surveys (to establish the boundaries of a parcel using its legal description) and subdivision plans (a plot or map based on a survey of a parcel of land, with boundary lines drawn inside the larger parcel to indicate the creation of new boundary lines and roads), both of which are generally referred to as Cadastral surveying.

Construction surveying

Construction surveying is generally performed by specialized technicians. Unlike land surveyors, the resulting plan does not have legal status. Construction surveyors perform the following tasks:

- Surveying existing conditions of the future work site, including topography, existing buildings and infrastructure, and underground infrastructure when possible;
- "Lay-out" or "setting-out": placing reference points and markers that will guide the construction of new structures such as roads or buildings;
- Verifying the location of structures during construction;
- As-Built surveying: a survey conducted at the end of the construction project to verify that the work authorized was completed to the specifications set on plans.

Transportation engineering

This is concerned with moving people and goods efficiently, safely, and in a manner conducive to a vibrant community. This involves specifying, designing, constructing, and maintaining transportation infrastructure which includes streets, canals, highways, rail systems, airports, ports, and mass transit. It includes areas such as transportation design, transportation planning, traffic engineering, some aspects of urban engineering, queueing theory, pavement engineering, Intelligent Transportation System (ITS), and infrastructure management.

Municipal engineering

This is concerned with municipal infrastructure. This involves specifying, designing, constructing, and maintaining streets, sidewalks, water supply networks, sewers, street lighting, municipal solid waste management and disposal, storage depots for various bulk materials used for maintenance and public works (salt, sand, etc.), public parks and cycling infrastructure. In the case of underground utility networks, it may also include the civilportion (conduits and access chambers) of the local distribution networks of electrical and telecommunications services. It can also include the optimizing of waste collection and bus service networks. Some of these disciplines overlap with other civil engineering specialties, however municipal engineering focuses on the coordination of these infrastructure networks and services, as they are often built simultaneously, and managed by the same municipal authority. Municipal engineers may also design the site civil works for large buildings, industrial plants or campuses (i.e., access roads, parking lots, potable water supply, treatment or pretreatment of waste water, site drainage, etc.)

Water resources engineering

This is concerned with the collection and management of water (as a natural resource). As a discipline it therefore combines elements of hydrology, environmentalscience, meteorology, conservation, and resource management. This area of civil engineering relates to the prediction and management of both the quality and the quantity of water in both underground (aquifers) and above ground (lakes, rivers, and streams) resources. Water resource engineers analyze and model very small to very large areas of the earth to predict the amount and content of water as it flows into, though, or out of a facility. Although the actual design of the facility may be left to other engineers.

Hydraulic engineering i

This is concerned with the flow and conveyance of fluids, principally water. This area of civil engineering is intimately related to the design of pipelines, water supply network, drainage facilities (including bridges, dams, channels, culverts, levees, storm sewers), and canals. Hydraulic engineers design these facilities using the concepts of fluid pressure, fluid statics, fluid dynamics, and hydraulics, among others.

UNIT 2- CIVIL ENGINEERING- SOCIETAL AND GLOBAL IMPACT

Civil engineering systems is a discipline that promotes the use of systems thinking to manage complexity and change in civil engineering within its wider public context. It posits that the proper development of civil engineering infrastructure requires a holistic, coherent understanding of the relationships between all of the important factors that contribute to successful projects while at the same time emphasizing the importance of attention to technical detail. Its purpose is to help integrate the entire civil engineering project life cycle from conception, through planning, designing, making, operating to decommissioning.

Managers of construction engineers oversee many types of projects, and they have many duties:

— Developing construction budgets for projects

— Gathering teams of workers, physical materials, machines, and tools

— Overseeing safety and productivity on job sites

— Using construction project management software

Geotechnical engineering has many responsibilities that are complex and demanding:

— Analysing soil samples in subsurface investigations

— Conducting field tests to determine issues that can pose safety risks on projects

— Analysing subsurface investigation and field tests with computer software

Some tasks that structural engineers are responsible for:

— Calculating loads and stresses that structures can safely endure

— Surveying job sites before work even begins to determine suitable requirements

— Assessing and monitoring structures like bridges, dams, and buildings

Transport engineers have complex tasks that include:

— Evaluating plans and proposals

— Analysing schematics and data from other engineers

— Offering recommendations for driving and traffic policies

Water engineering covers the following:

— Designing flood defence plans and sewer improvement programs

— Staying aware and up to date with policy and developments

— Crafting strategies for flood defence

Environmental engineers are responsible for tasks that include but not limited to:

— Reviewing environmental investigation reports

— Designing projects that lead to environmental protection

— Monitoring progress of environmental improvement programs

— Analysing scientific data & conducting quality-control checks

— Advising government and corporate agencies about procedures on contaminated sites.

Some tasks that involve coastal engineers are the following:

— Managing shoreline erosion

— Managing pollution in proximate marine environments

— Improving navigation channels and harbors

— Improving coastal recreation

— Protecting buildings from a flood brought on by storms, waves, tides

Within forensic engineering, there are many common tasks:

— Identifying failure of product, machine, building

— Collecting evidence to determine the hypotheses of failure

— Offering a conclusion to the likely cause of the failure from analysis

What types of projects do civil engineers work on?

CIVIL ENGINEERING PROJECTS:

Standard Analysis or Design

In a standard analysis or design project, civil engineers write up reports and create a few drawings for the project. Although not always asked for, civil engineers might go the extra mile and draft up

more than one idea. This is so there can be a proper discussion on which design or idea is more suitable for the project and why. Examples of this kind of project are main water designs, capacity analysis of highways, and improving storm drainage. Of the types of civil engineering projects, structural engineering would fall into this category the most.

Developing New Solutions

In a project about developing new solutions, you have to understand what the initial problem is, write a proposal on how to solve this problem, test your proposal, and see if the problem has been solved. Out of the five types of civil engineering projects, geotechnical engineering is a perfect example because the ground is never the same for a project.

Conclusion

Civil engineers made many of the structures we see every day. Bridges, roads, dams, railways, highways, and more have all been created by civil engineers. To say they have a huge impact on our lives would be an understatement. There are many types of civil engineering projects, but each one has an important role to fill. Without these projects, our society would not come close to being as advanced as we are now.

Socio-economic development and civil engineering:

There are several recommendations arising from the research to help the infrastructure sector maximise social value. Here are some of the key recommendations arising from the research that are relevant to civil engineers:

1. **Invest in the right project**

   So much can be achieved by investing in the right project. Infrastructure clients should be more willing to explore alternative solutions that may deliver greater social value and integrate with other local infrastructure projects to maximise benefits to society.
2. **Embrace a broad view of social value**

   A crucial first step is for all stakeholders in the infrastructure sector to understand that social value goes beyond just delivering employment, apprenticeships and SME involvement during construction. We need to think broadly about how the infrastructure asset can improve the lives of local people and deliver multiple benefits beyond the redline boundary. Thames Tideway is a great example of a project that is doing this well, and a case study is included in the publication.
3. **Aim to create social value at all stages of the project lifecycle**

   The current focus on delivering social value through the procurement and delivery phase means that opportunities to create benefits upstream (during strategic brief, business case, planning and design) and downstream (during operations and decommissioning) are being lost. The research report sets out key steps for closing the current implementation gap

between organisational policy objectives on social value and delivery on the ground, for each stage in the project lifecycle.

4. **Base social value interventions on a Local Needs Analysis**

- Social value interventions should deliver benefits that meet the specific needs of the affected communities; helping to build stronger and more resilient villages, towns and cities. Clients should conduct or commission a Local Need Analysis in advance of finalising a project's strategic brief.
- This should assess local needs beyond the project redline boundary and include engagement with a wide group of local stakeholders.
- Civil engineers play a major role in the infrastructures development of a country. All structures constructed in the past exhibit the path of civilization and current infrastructures development express the practices followed by civil engineers.
- Infrastructure can be defined as activities that provide society with services necessary to conduct daily life and to engage in productive activity and development in a country's economy.
- In a country like India, the major infrastructural. Factors that are most significant in accelerating the pace of economic development are energy, transport, irrigation, finance, communications, education, and health.
- The knowledge of basic areas of civil engineering can be of great use in providing the infrastructural facilities where constructional aspects are involved for development of regions.

Infrastructure facilities include

- Good surface communication links such as tar or concrete rods.
- Provision of water supply distribution system i.e. construction of water storage reservation or sumps, laying of underground pipes etc.
- Provision of a drainage system which may include construction of surface drains as subsurface drains for the disposal of wastewater.
- Supply of electrical power for which construction of transmission line towers, construction of electrical substations.
- Providing inland communications lines, i.e telephone lines etc.
- Construction of recreational places e.g gardens, parks etc.

What is Facility Management

Facility management (FM) is a profession that encompasses multiple disciplines to ensure functionality, comfort, safety and efficiency of the built environment by integrating people, place, process and technology.

What is Facility Management

Who manages one of your organization's largest assets with one of the largest operating budgets? Your facility manager.

Facility management (FM) is a profession that encompasses multiple disciplines to ensure functionality, comfort, safety and efficiency of the built environment by integrating people, place, process and technology.

WHAT DO FACILITY MANAGERS DO?

Facility managers (FMs) can have many different titles and arrive in their profession through a variety of career paths. They're responsible for making sure systems of the built environment, or facility, work harmoniously. They are important because they make sure the places in which people work, play, learn and live are safe, comfortable, productive and sustainable.

FMs contribute to the organization's bottom line through their responsibility for maintaining what are often an organization's largest and most valuable assets, such as property, buildings, equipment and other environments that house personnel, productivity, inventory and other elements of operation. Here are some of the ways FMs contribute to an organization's business strategy and bottom line:

- Impacting operational efficiencies
- Supporting productivity of facilities and personnel
- Managing risks to facilities and personnel
- Mitigating environmental impact
- Promoting sustainable tactics for long-term cost management
- Leveraging technological solutions

- Reducing or overcoming effects of natural disasters
- Guaranteeing compliance
- Leveraging security

Energy efficient building design involves constructing or upgrading buildings that are able to get the most work out of the energy that is supplied to them by taking steps to reduce energy loss such as decreasing the loss of heat through the building envelope. Energy efficient homes, whether they are renovated to bemore efficient or a built with energy efficiency in mind, pose a significant numberof benefits. Energy efficient homes are less expensive to operate, more comfortable to live in, and more environmentally friendly.

Inefficiencies that are not removed in the building process can pose issues for years. However, keeping energy efficient building design in mind when construction is underway is a more effective way to approach making a home more efficient, which is less expensive for a homeowner in the long run. Buildingcodes exist around the world to ensure that buildings are energy efficient to a certain degree, however sometimes it is wise to go above and beyond these recommendations to have an even more energy efficient home. As well, since a house operates as a system, a home must be looked at as a whole in order to fully increase the energy efficiency. For example, expensive heating and cooling equipment do nothing to improve the energy performance of the houseif insulation isn't keeping heat in during the winter and out in the summer.

Building an Energy Efficient Home

There are numerous ways to increase the energy efficiency of a building, and many different parts of a building that can be improved to boost this value. Better insulation, more efficient windows, doors, and skylights, as well as high- efficiency air conditioners and furnaces can all contribute to a more efficient homeby keeping warm air inside or outside the home. As well, being able to properly regulate the temperature of a home through the use of a thermostat is amajor part of having an energy efficient home, as having the right equipment is just as important as using it properly.

Overall, there are numerous strategies to increase energy efficiency. These steps include:

- Using proper amounts of insulation in the walls and roof, being sure to reference regional standards
- Properly weatherizing the building using weather stripping and caulking
- Installing high quality windows that utilize low-e coatings and gas filling, while choosing the glazing and window frame material that will be most beneficial in the environment
- Installing high-performance systems and appliances and evaluate their performance over their life cycle
- Monitoring and verifying performance through energy audits to see where energy is being wasted in a building and where it is most cost-effective to make improvements through retrofitting

Overall, the general approach to achieving high efficiency buildings includes cutting the energy demand of buildings, producing energy locally from renewable

resources, and sharing energy by creating buildings that generate a surplus of energy that can be fed back into an advanced grid structure.

Leadership in Energy and Environmental Design (LEED)

Leadership in Energy and Environmental Design (LEED) is a green building certification program used worldwide. Developed by the non-profit U.S. Green Building Council (USGBC), it includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighbourhoods, which aims to help building owners and operators be environmentally responsible and use resources efficiently.

LEED is a design tool rather than a performance-measurement tool and focuses on energy modelling rather than actual energy consumption. It lacks climate specificity, and has been criticized for a point system that can encourage inappropriate design choices and make energy conservation the weakest part of the evaluation. It has also been criticized for the phenomenon of "LEED brain" in which the public relations value of LEED certification drives the development of buildings.

LEED BENEFITS

According to the USGBC.org website, LEED certification will provide the following benefits:

- **Gain a competitive edge** – 61% of corporate leaders believe that sustainability leads to market differentiation and improved financial performance.
- **Attract tenants** – LEED-certified buildings command the highest rents, while lease up rates typically range from average to 20% above average; vacancy rates for green buildings are an estimated 4% lower than non-green properties.
- **Manage performance** – LEED is the world leading green building project and performance management system. It delivers a comprehensive framework for green building design, construction, operations and performance.
- **Meet ESG goals** – LEED helps investors meet their ESG goals by providing investors with the robust and globally recognized green building framework to measure and manage their real estate performance.

LEED CERTIFICATION REQUIREMENTS

Qualifying for the USGBC's LEED certification is a very in depth process that involves extremely detailed standards and guidelines. The certification requires mathematical calculations and detailed documentation of design, materials and construction. The certification scores green building design and construction using a point system that is categorized in five areas:

- **Sustainable sites**
- **Water efficiency**
- **Energy and atmosphere**
- **Materials and resources**
- **Indoor environmental quality**

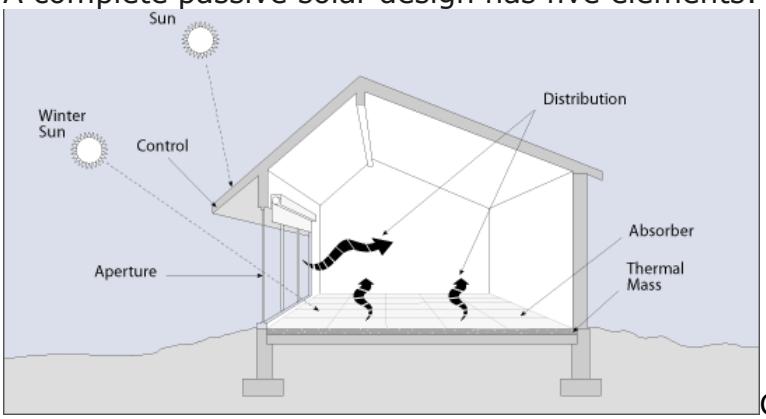
Temperature Control In buildings using Solar Passive Techniques

Passive solar design refers to the use of the sun's energy for the heating and cooling of living spaces by exposure to the sun. When sunlight strikes a building, the building materials can reflect, transmit, or absorb the solar radiation. In addition, the heat produced by the sun causes air movement that can be predictable in designed spaces. These basic responses to solar heat lead to design elements, material choices and placements that can provide heating and cooling effects in a home.

Unlike active solar heating systems, passive systems are simple and do not involve substantial use of mechanical and electrical devices, such as pumps, fans, or electrical controls to move the solar energy.

Passive Solar Design Basics

A complete passive solar design has five elements:



Graphic courtesy of EERE

- **Aperture/Collector:** The large glass area through which sunlight enters the building. The aperture(s) should face within 30 degrees of true south and should not be shaded by other buildings or trees from 9a.m. to 3p.m. daily during the heating season.
- **Absorber:**The hard, darkened surface of the storage element. The surface, which could be a masonry wall, floor, or water container, sits in the direct path of sunlight. Sunlight hitting the surface is absorbed as heat.
- **Thermal mass:** Materials that retain or store the heat produced by sunlight. While the absorber is an exposed surface, the thermal mass is the material below and behind this surface.
- **Distribution:** Method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use the three natural heat transfer modes- conduction, convection and radiation- exclusively. In some applications, fans, ducts and blowers may be used to distribute the heat through the house.
- **Control:** Roof overhangs can be used to shade the aperture area during summer months. Other elements that control under and/or overheating include electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; low-emissivity blinds; and awnings.

Passive Solar Heating

The goal of passive solar heating systems is to capture the sun's heat within the building's elements and to release that heat during periods when the sun is absent, while also maintaining a comfortable room temperature. The two primary elements of passive solar heating are south facing glass and thermal mass to absorb, store, and distribute heat. There are several different approaches to implementing those elements.

Direct Gain

The actual living space is a solar collector, heat absorber and distribution system. South facing glass admits solar energy into the house where it strikes masonry floors and walls, which absorb and store the solar heat, which is radiated back out into the room at night. These thermal mass materials are typically dark in color in order to absorb as much heat as possible. The thermal mass also tempers the intensity of the heat during the day by absorbing energy. Water containers inside the living space can be used to store heat. However, unlike masonry water requires carefully designed structural support, and thus it is more difficult to integrate into the design of the house. The direct gain system utilizes 60-75% of the sun's energy striking the windows. For a direct gain system to work well, thermal mass must be insulated from the outside temperature to prevent collected solar heat from dissipating. Heat loss is especially likely when the thermal mass is in direct contact with the ground or with outside air that is at a lower temperature than the desired temperature of the mass.

Indirect Gain

Thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. The indirect gain system will utilize 30-45% of the sun's energy striking the glass adjoining the thermal mass.

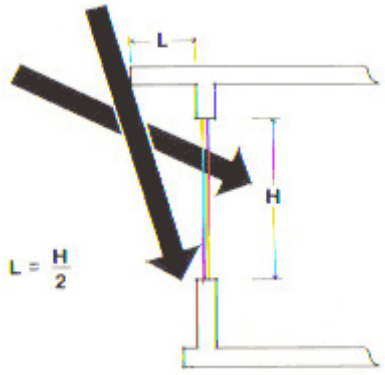
The most common indirect gain systems is a Trombe wall. The thermal mass, a 6-18-inch-thick masonry wall, is located immediately behind south facing glass of single or double layer, which is mounted about 1 inch or less in front of the wall's surface. Solar heat is absorbed by the wall's dark-coloured outside surface and stored in the wall's mass, where it radiates into the living space. Solar heat migrates through the wall, reaching its rear surface in the late afternoon or early evening. When the indoor temperature falls below that of the wall's surface, heat is radiated into the room.

Operable vents at the top and bottom of a thermal storage wall permit heat to convect between the wall and the glass into the living space. When the vents are closed at night, radiant heat from the wall heats the living space.

Passive Solar Cooling

Passive solar cooling systems work by reducing unwanted heat gain during the day, producing non-mechanical ventilation, exchanging warm interior air for cooler exterior air when possible, and storing the coolness of the night to moderate warm daytime temperatures. At their simpliest, passive solar cooling systems include overhangs or shades on south facing windows, shade trees, thermal mass and cross ventilation.

Shading



Overhang design for shading. Diagram courtesy of the Arizona Solar Center. The steeper arrow shows the angle of the sun's rays during the summer, while the shallower arrow indicates the angle during the winter.

To reduce unwanted heat gain in the summer, all windows should be shaded by an overhang or other devices such as awnings, shutters and trellises. If an awning on a south facing window protrudes to half of a window's height, the sun's rays

will be blocked during the summer, yet will still penetrate into the house during the winter. The sun is low on the horizon during sunrise and sunset, so overhangs on east and west facing windows are not as effective. Try to minimize the number of east and west facing windows if cooling is a major concern. Vegetation can be used to shade such windows. Landscaping in general can be used to reduce unwanted heat gain during the summer.

Thermal Mass

Thermal mass is used in a passive cooling design to absorbs heat and moderate internal temperature increases on hot days. During the night, thermal mass can be cooled using ventilation, allowing it to be ready the next day to absorb heat again. It is possible to use the same thermal mass for cooling during the hot season and heating during the cold season.

Ventilation

Natural ventilation maintains an indoor temperature that is close to the outdoor temperature, so it's only an effective cooling technique when the indoor temperature is equal to or higher than the outdoor one. The climate determines the best natural ventilation strategy.

In areas where there are daytime breezes and a desire for ventilation during the day, open windows on the side of the building facing the breeze and the opposite one to create cross ventilation. When designing, place windows in the walls facing the prevailing breeze and opposite walls. Wing walls can also be used to create ventilation through windows in walls perpendicular to prevailing breezes. A solid vertical panel is placed perpendicular to the wall, between two windows. It accelerates natural wind speed due to pressure differences created by the wing wall.

In a climate like New England where night time temperatures are generally lower than daytime ones, focus on bringing in cool night time air and then closing the house to hot outside air during the day. Mechanical ventilation is one way of bringing in cool air at night, but convective cooling is another option.

Convective Cooling

The oldest and simplest form of convective cooling is designed to bring in cool night air from the outside and push out hot interior air. If there are prevailing nigh time breezes, then high vent or open on the leeward side (the side away from the wind) will let the hot air near the ceiling escape. Low vents on the opposite side (the side towards the wind) will let cool night air sweep in to replace the hot air.

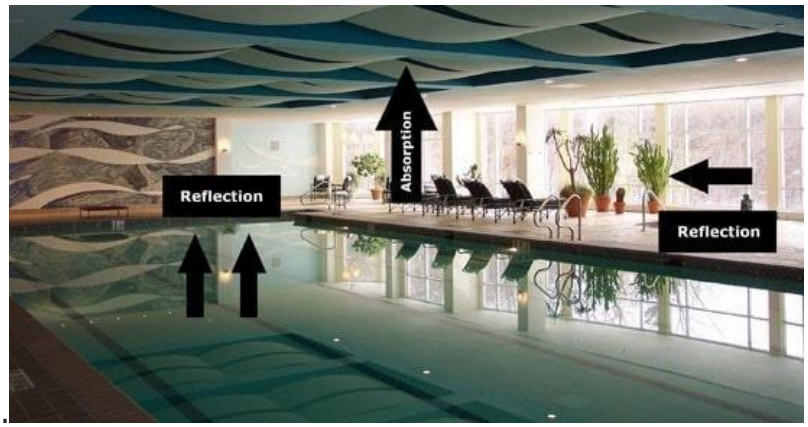
At sites where there aren't prevailing breezes, it's still possible to use convective cooling by creating thermal chimneys. Thermal chimneys are designed around the fact that warm air rises; they create a warm or hot zone of air (often through solar

gain) and have a high exterior exhaust outlet. The hot air exits the building at the high vent, and cooler air is drawn in through a low vent.

There are many different approaches to creating the thermal chimney effect. One is an attached south facing sunroom that is vented at the top. Air is drawn from the living space through connecting lower vents to be exhausted through the sunroom upper vents (the upper vents from the sunroom to the living space and any operable windows must be closed and the thermal mass wall of the sunroom must be shaded).

Noise control

Noise control inside a building can be achieved by following construction techniques while construction of a building. The construction techniques of walls, windows, doors and floors and selection of appropriate building materials are discussed for better acoustic control in buildings. The discomfort of noise within the building goes on increasing if the structural elements within the building too don't show any resistance against the noise. It is found that the noise transmission is intercepted when it passes through the walls, floors, windows, ceilings and the building doors



The Sound Transmission Class (STC)
A certain parameter has to be used in order to compare the performance of different construction materials. One such parameter is the sound transmission class(STC). The sound transmission class can be defined as the numerical value equal to the number of decibels in terms of reduction of sound when it passes through a material, which is intended to have some insulating property. This can make one understand that a high value of STC implies the material possess a high insulating property. It basically works on the influence of external frequencies of the areas of the partition where the sound originates and where the receiving of the sound takes place. This can be explained by an example. Let us assume the desired level of sound internally is 45 decibels and the external level of noise is 85decibels, then we require a partition material that has a sound transmission class value of 40 STC for adequate acoustic comfort. STC is a sound transmission class rating which is put forward by the **American society of Testing and Measurement**. This acts as a parameter to guide an architect to know which

material would suit the most, to have an essential acoustic feature by the reduction of noise.

Construction Techniques in Acoustic Planning of a Building
The structural elements and their construction for controlling noise in buildings are mentioned below.

Construction of Walls for Noise Control in Buildings
Wall are an important structural element in all kind of buildings, that provides protection from the noise externally as well as internally. The usage of different wall materials or the usage of different design for the wall would bring variation in the insulating properties of the element. The figure below shows the differencein sound attenuation with variation in wall design. The methods employed for noise control in buildings are explained in the following:

1. Wall Mass and the Thickness are Increased
The massiveness of a material is an efficient parameter that resists noise. Hence concrete walls are more insulating than wooden walls. Another way of increasing the insulating property is to add more thickness for the walls. The increase of thickness of walls would result in more mass which in turn increase insulation. A reduction of 6 decibel sound happens by this method of construction. But the techniques must be carried out keeping in mind the cost and economy. Wall construction that undergoes vibration under huge frequencies of sound has to be avoided.

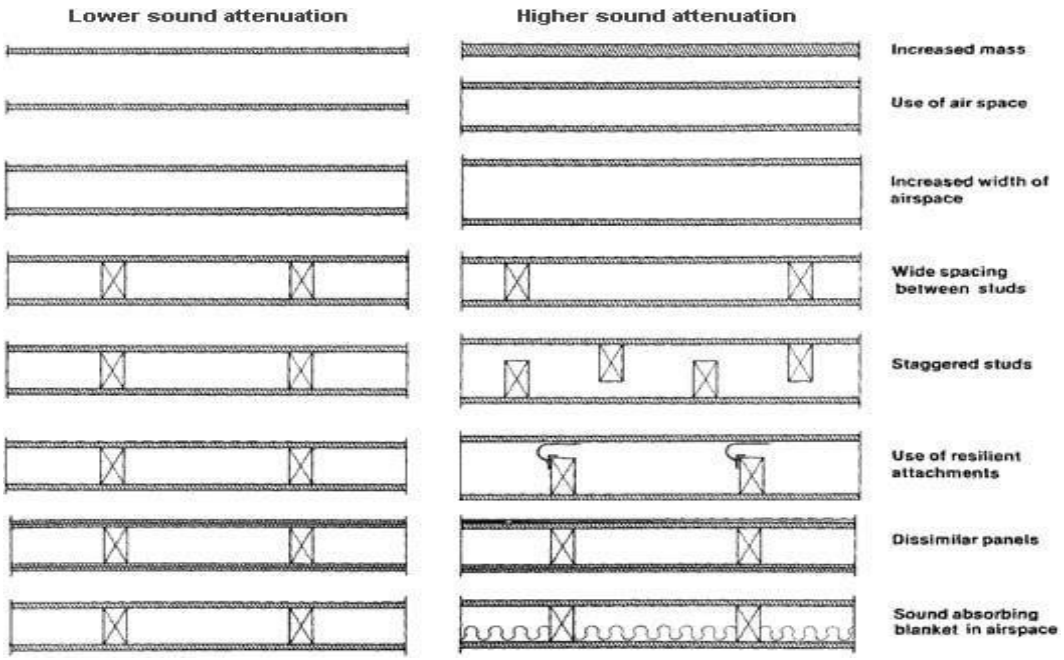


Fig.1. Different Wall Design Techniques Showing the Variation of Sound Attenuation

2. Use of Cavity Partition in Buildings for Noise Control
The sound transmission can be resisted by the usage of airspace between the two partition walls. The air space can also be placed in between two or more layers.

This concept is more effective than a single wall of equal weight, which is found to be more economical.

3. Increase Airspace Width of Walls
The increase in airspace will obviously increase the noise insulation property. But the huge increase in the width of air space is difficult to design and consumes more space.

4. Increasing the Stud Spacing
It is found by a study that the spacing between the studs would increase the sound transmission capacity of the room. Say an increase of 2 to 5 decibel STC is determined for a stud spaced 24 inches than those spaced at 16 inches.

5. Usage of Studs in a Staggered Manner
The arrangement of studs in a staggered manner as shown in figure-1, where studs are placed alternatively would help in noise absorption, thus reducing noise intensity.

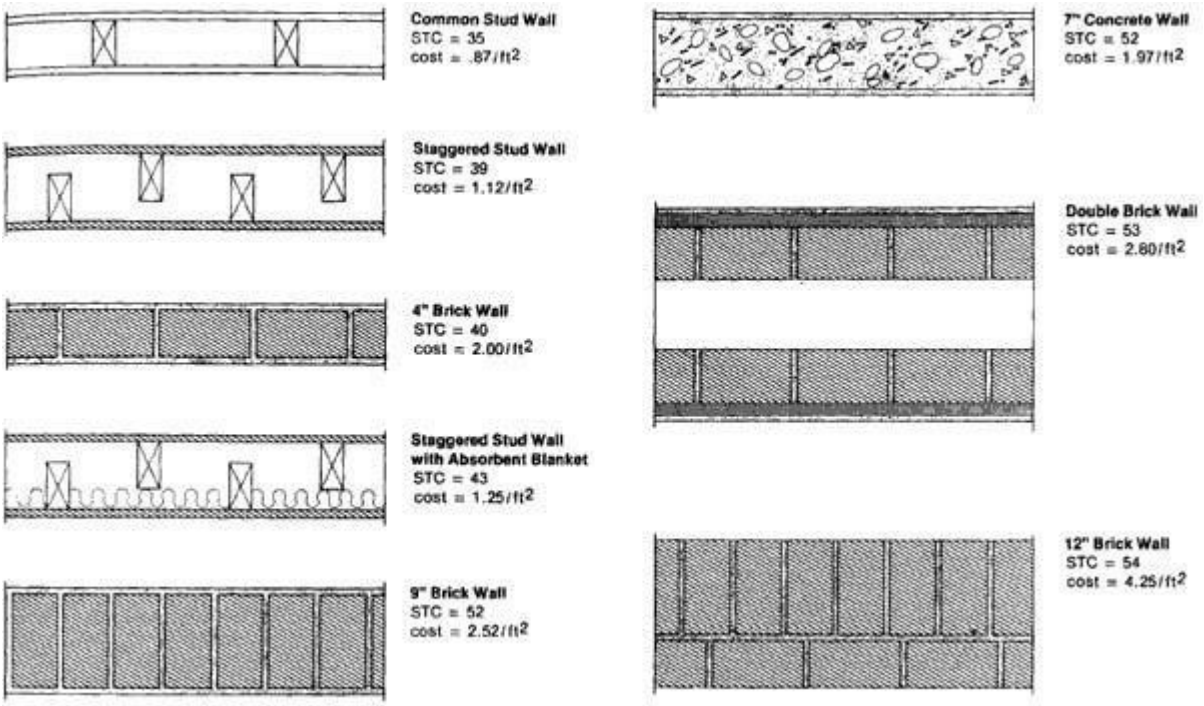


Fig.2. Figure Shows Variety of Wall Types, their Cost Comparison and STC Values

6.Studs and Panels held together by Resilient Materials
Making use of inexpensive resilient layers like glass or fiber board, or semi-resilient attachments which are inert in nature, will help in reducing the STC rate by two to five decibels.

7. Panels Used are Dissimilar
Using different thickness and materials for panels would help in reduction of noise, thus increasing the sound insulating quality of walls.

8.Sound Absorbing Blankets Used in the Airspace
The sound absorbing blankets are also called as isolation blankets which are placed in the airspace arrangement, that are provided between the panels. This blanket enables an increase in sound attenuation. Mineral or rock wool, wood fibers or fiberglass are some the materials used to make these blankets. These blankets have an attenuation capability up to 10 decibels. The method is more effective where lightweight construction is more prominent.

9.The Cracks and Edges are Sealed
The full advantage of a high-performance wall can be brought out only when it is properly sealed and crack free. The perimeter of the wall must be properly sealed. Formation of cracks or holes would affect the insulation property of the wall. It has been observed that a hole of the 1-inch square will result in a reduction of STC of the wall by 10.

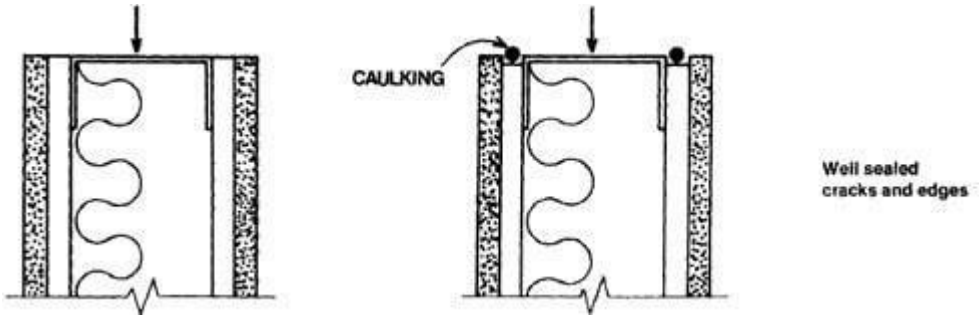
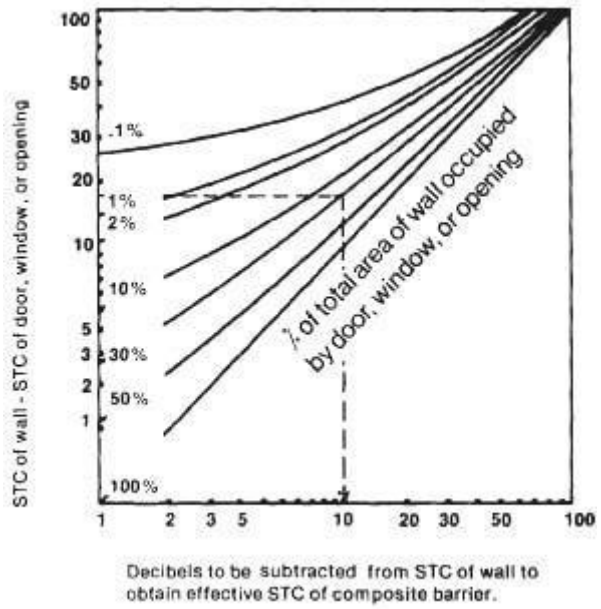


Fig.3. Depicts Before and After the Sealing of Cracks

Construction of Windows for Acoustic Control in Buildings
Windows are one of the weakest elements of a building. Their inappropriate position or open condition would affect the performance of insulating walls. Therefore, it is recommended to have acoustical consideration in the arrangement of windows. The graph below shows the variation of STC values of the wall, for the different area occupied by the windows which are shown in percentages.



The following measures can be employed to reduce the noise entering the building through the windows:

1. Windows can be Closed

Permanent sealing or closing of the windows are the best measures to reduce the direct effect of noise. Permanent sealing becomes essential when an air conditioning system must be enabled. So, sealing acts as a constant solution for noise. The masking of noise is an effect that is facilitated by the air conditioning system, which is discussed in the following topics.

2. Windows Size can be Reduced

The loss of contribution of total partitions can be reduced by making the window size to small. Small windows do have certain other advantages like:

- Expensive acoustic windows can be excluded
- Usage of glass is reduced

The method faces certain disadvantages too. The decrease of window size is limited, as the window size should follow certain rules and regulations. Itsdecrease by, say from 50 to 20 % would only bring up a change of 3 decibels.

3. Glass Thickness can be Increased

The more thickness the glass gains, the more resistant towards the noise. If sealing is not desired, the glass thickness can be increased. Further, the glass can be laminated with a tough plastic, which is transparent in nature. This is both shatter and noise resistant.

Construction of Doors for Acoustic Control in Buildings

Doors are considered very difficult to handle than windows, acoustically. Replacing a hollow core door by a solid door is one of the solutions. This is found relatively

expensive. The sound insulation can be increased if at the bottom and at the top, a drop bar or gasket stops are installed. Another solution is to reduce their use in walls facing noise directly. Install doors on the wall that is shielded.

Construction of Floors for Acoustic Control in Buildings
Special acoustical treatment is the only way to reduce the vibration of floors due to heavy noise. Installing a heavy concrete floor or using a floating floor is some of the treatment methods. Floating floor involves using a concrete or wooden slab over the existing one, which is separated by a resilient material.

Noise Control in Buildings by use of Masking
This method involves the drowning of noise with the help of a background noise. This is effective during noise fluctuations. Masking can be created by soft music, electronic devices or air conditioning systems and heating systems

Recycling of Building Materials
The best way to recycle construction waste is using it in new projects, and there are many construction materials that can be recycled. The following are some examples:

- Concrete
- Metals
- Asphalt
- Wood and untreated timber
- Glass
- Paper and Cardboard
- Gypsum
- Masonry
- Appliances and fixtures, such as sinks and bathtubs
- Windows, doors, and roofing
- Vegetation and trees
- Plastics

Environmental Benefits from Recycling Construction Materials

Recycling construction materials has two main environmental benefits: it saves energy and it reduces landfill waste.

Energy Savings: Recycling saves large amounts of energy, and in general it decreases the consumption of natural resources to produce new materials. For example, if all the concrete and asphalt waste generated annually in the US were recycled, it would save the energy equivalent of 1 billion gallons of gasoline.

Landfill waste reduction: Landfills are filling up, which means that alternative ways to manage waste must be developed. Recycled construction waste can be reused as it is, or turned into something new.

- Recycling eliminates the need to send waste to landfill sites.
- Processing hazardous waste properly minimizes toxic build-up in the environment.

Economic Benefits of Recycling Construction Materials

Cost Savings: Recycling and reusing construction materials reduces the cost of disposal and transportation. Some recycling organizations even charge less compared with conventional disposal methods. Recycling also reduces the demand for new resources, which also cuts transportation and production costs.

Green Certifications: Construction companies that recycle materials have a competitive edge, due to the increasing importance of green building and environmental conservation. Recycling can help building owners earn points for LEED certification, which is the most popular green building rating system.

Tips for Recycling Construction Materials

Planning
Like any aspect of a project, recycling should be carefully planned before starting. Organizations such as environmental agencies can help you implement best practices for your project, while making sure it follows local regulations.

Recycling Regulations
Understanding local waste and landfill rules is necessary before starting any project. Municipal solid waste departments can provide the necessary information, including the use of landfills and recycling guidelines.

Using Standard Dimensions
When designing a new building, consider using the standard dimensions of common materials. This reduces the cutting required, producing less waste during construction, while also saving time and labor.

Local Recycling Centers
Recycling centers can help you dispose of construction waste, but make sure you analyze the distances involved. If the center is located far from your project, consider other alternatives. Waste deliveries to a recycling center can be planned along with large material purchases and other project activities, saving on transportation.

Recycling centers have rules and regulations; make sure you ask which materials are accepted and if separation is required.

Deconstruction
Another way to reduce construction waste is with deconstruction, also known as selective dismantling. There are some organizations that separate construction materials and reuse them for social housing projects, which provides tax advantages. Another option for small projects like house renovations is selling the recycled materials directly.

Estimating Cost Savings
As mentioned before, recycling construction materials is not only beneficial for the environment. It also opens opportunities for cost savings and higher profits. The savings from recycling can be tracked as part of your normal accounting process.

Designing a Barrier Free Built Environment
More than a tenth of the world's population suffers from some kind of disability. A well-designed environment that is safe, convenient, comfortable, and readily accessible is highly beneficial for empowering the disabled and others as well. It is awaited that design professionals, the building industry, government, the community will implement them and generate awareness about the criticality of Barrier Free Built Environment. The considerations below should be further advanced by accurate signage, braille, and tactile to completely transform the environment for the users.

A good design does not differentiate, let us investigate how to make our habitats more inclusive.

Building Entrance

All the public domains of a building should be accessible to all as a rule and break the general notion to have a provision of steps to move across levels of buildings. The designs should be ergonomically sound, hence a detailed study of wheelchairs, height of location of handrails, material of the ramp, the capacity of the building, etc needs to be done beforehand. For visually impaired people, ramps may be colour contrasted with landing.

Minimum width of the ramp & clear landing- 1800mm (CPWD Guidelines)

Gradient- not steeper than 1:12, preferably 1:15 to 1:20

Handrails on both sides- height 900mm (children-760mm), extended beyond 300mm from the top and bottom.

Staircase & Lift

Stairs should not be the only means of movement between floors, accompanied by lifts & ramps. Straight flights of steps are preferred by ambulant disabled people, preferably not more than 11 steps at a go without leveled landing. Treads must be consistently 300 mm deep and risers 150 mm, supported with handrails on both sides (avoid open stairs). For a visually impaired person, colour contrast between the front edge of each step to enable their vision (winder, spiral staircase, and splayed step should be avoided).

Elevators should be chosen keeping in mind, the wheelchair movement & anthropometrics of the person using them. For visually impaired people, they should be at eye level. Information should preferably be in relief for tactile reading with colour contrast & audible signals indicating opening/closing of doors.

Controls and the call button - 900mm - 1200mm from the floor.

Clear entrance width- 850 mm

Minimum Internal Car dimensions- 2000mm x 1100mm

Pathway & Lobby

Spaces to be curated such that difference in levels is avoided without proper provision of ramps. Protruding objects (signs, drinking fountain, fire extinguisher, the underside of stairway/escalator, etc.) can be extremely hazardous to the persons with visual impairment as well as the public and attempted to be recessed into the wall. Wayfinding for those with visual impairment made easier by surfaces and finishes with luminous contrast between the wall and the ceiling, and between the wall and the floor should be adopted. Appropriate lighting design withadequate illumination (30% luminous contrast) can also be implemented.

Maneuvering space not less than 1500 mm x 1500 mm (within 3500 mm of every dead end)

Minimum length of the lobby - 1200 mm (excluding space for door swings)

Minimum 900mm unobstructed open space where doors are opening into the corridor.

Toilet & Bathroom

Every public building comprises at least one WC cubical for the ambulant disabled. Generally, such users require more space for proper accessibility in such rooms. Washbasins must be mounted at 750mm from floor level with a clearance of 550mm below powered by an easily operable tap (no wrist twisting). Shower compartments (1500 mm x 900 mm) encompass L-shaped bars for support, hand-held showerheads (below 900mm), and self-draining shower seats for optimal functioning. An easily operable push button should be provided in any individual accessible toilet compartment to summon assistance at the seated position or on the floor in case of emergency.

Standard Japanese Handicap Toilet. Image credits: lulzmachine, Reddit

Minimum Dimension WC cubicle- 2200mm x 1750mm

Door- 900mm wide (swinging out)

Handrails on each side parallel to the floor- 750 mm high

WC mounting height from floor- 500mm

Flushing control (on the wide side) at height 600 mm to 1050 mm above floor level.

Door

Doors need to be properly articulated for unaided movement of the specially-abled. The visual contrast between the door and frame with the adjoining wall or colour bands marking the frame in the case of glass doors helps the visually challenged. Public buildings should preferably have sliding automatic doors with sensors or door closing devices with a minimum time delay of 5 seconds.

The minimum clear width should be 900 mm (operable by a single effort).

Handle- 800 mm from the floor level.

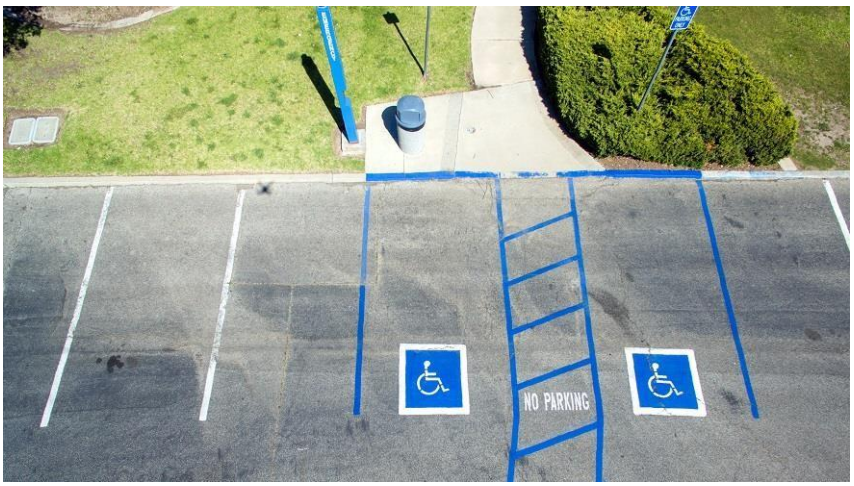
Kick-plates- 200 mm high fitted on the face which swings away for wheelchair users.

Parking

The parking spaces should be calculated and reserved for persons with a disability. Proximity to the entrance and accessible route to the lobby (with an accessible lift or entrance) should be pre-planned. The parking space is marked with the international signage for disability and directional signage along the driveway showing the way leading to the reserved parking space.

Minimum width for a parking space - 3600 mm (including loading/unloading area)

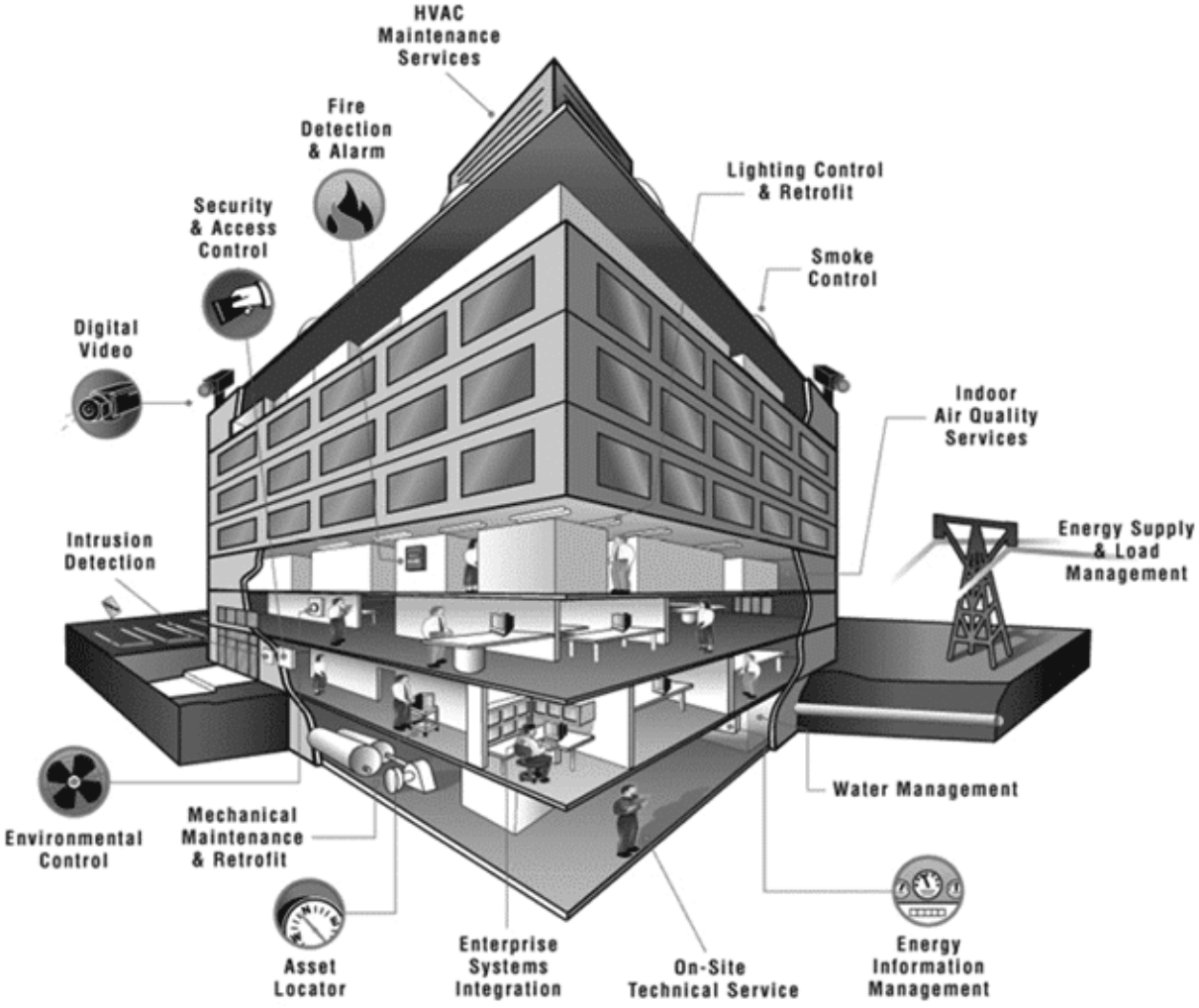
Hatched loading/unloading area (common for 2 adjacent cars) – 1200mm



Building security and control system

Building security and control system have become necessary with increasing size and complexity of buildings. The building security and control system is designed to monitor and control mechanical and electrical installations, fire protection and escape, burglary, assault and emergency communication.
In tall buildings and major complexes, the most important security requirement is fire-safety system. In addition to the structural precautions for fire protection, special system is required to monitor and control are:
1. Fire detection and suppression,
2. Movement and protection of people
3. Smoke control including pressurization and barriers
4. Safe places of refuge and
5. Emergency arrangements and communication.

In major buildings, these arrangements are integrated with those required to monitor and control the heating, ventilation and air-conditioning systems and other aspects of security within a single electronic system. The computer monitors all significant local conditions and appropriate action is taken.



Such measures for security and control could bring in the use of:

- Heating, ventilation and air-conditioning plant and equipment to suit internal and external conditions or programmed requirements.
- Data collection for maintenance and resource management, particularly energy use and analysis, programmed responses to suit anticipated emergencies, e.g. defining smoke-free zones and escape routes in the event of fire, and
- Security interlocks, surveillance and access control.

Energy management system (EMS), building automation system (BAS) and Building Management System (BMS) are used to describe these systems. The EMS controls the environmental functions, the BAS controls the technical automation and BMS includes such matters as status reports on environmental conditions, lifts and location of people for security purpose. All these are influenced, and influenced by the overall building designs.

The problems of building security is not only limited to major building complexes. With also depends on crime rates, density, size and tenant income, the nature of surrounding areas, building design characteristics etc..

Technology is a great ally to optimize the resources of a building and to improve its security.

This is becoming increasingly clear to thousands of people around the world. Especially those who live in a smart city. According to Markets and Markets, the global smart building market will experience enormous growth in the coming years, reaching 105. 8 billion dollars by 2024.

A considerable increase if we consider that in 2019 this same market had a turnover of 60. 7 billion dollars. These data show a growing trend towards the construction of smart buildings.

People are aware of the advantages that technologies bring to buildings and how the functionalities of an intelligent building allow complex activities to be carried out easily and improve the safety of the building, among other things.

But before going into detail about the benefits of smart buildings, it is worth addressing the definition of a smart building.

What is a smart building?

The different definitions of a smart building that exist coincide in affirming that they are buildings that have a smart infrastructure that is in charge of **obtaining information to automate different processes** such as lighting, access, air conditioning, video surveillance, parking, or security.Thanks to the data obtained through IoT (Internet of Things) devices and their interconnection, a building can **automatically manage all the resources optimizing their performance**. It can also provide valuable information for an

individual to **make better decisions** to further improve the livability and efficiency of the building. The functionalities offered by smart buildings go beyond home automation systems.

What features does a smart building have?

A smart building offers the following features:

Connecting building systems

A modern building incorporating the latest technology is one that connects all the equipment and systems that exist in a building. In this way, you can be informed of **what is happening in real time** and **access the historical records** of what happened a few minutes, hours or days ago so that you can act on the building's systems remotely in case of an emergency.

Connecting people and technology

Intelligent buildings are those that allow people to take advantage of the latest technological innovations in a simple and intuitive way. For example, accessibility for the disabled, with automated door opening, fall detection, voice control, etc.

Controlling the building's expenditure

The use of technologies to build intelligent buildings allows their users to reduce the money spent on different supplies such as heating, light, water, etc.

Centralized control of building behaviour

Anyone with access to a centralized platform is able to visualize in a screenshot the behaviour of the building to make the necessary adjustments. It is possible to control and automate systems such as lighting, power sockets, heating, air conditioning, appliances, doors, windows, blinds, irrigation, DHW generators, etc.

Connecting the building to a smart grid

In the next few years, buildings will become more sustainable and efficient, and we will see that they are increasingly able to predict the ambient temperature and contract light according to their needs, such as when the kilowatt is cheaper.

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2021-2022

Handout-Basics of Civil Engineering & Engineering Mechanics –CV14/24

Topic no.	Topics
1	Water Management- Traditional and Futuristic Systems
2	Flood Control
3	Multipurpose water projects
4	Water Sharing Techniques

1. Topic: Water Management- Traditional and Futuristic Systems

Water scarcity is being driven by two converging phenomena: growing freshwater use and depletion of usable freshwater resources. Water use has been growing globally at more than twice the rate of population increase in the last century, and an increasing number of regions are reaching the limit at which water services can be sustainably delivered, especially in arid regions. Water scarcity will be exacerbated as rapidly growing urban areas place heavy pressure on neighbouring water resources.

Water management, therefore, is the need of time. It is the management of water resources for the coming generations. It involves the activity of planning, developing, distributing and managing the optimum use of water resources which are defined by many policies and regulations.

The activity of movement and control of water resources to minimize the damage to property and life and also to maximize the efficient beneficial use is known as water management. If the management of water is good in dams and levees it reducesthe risk of harm caused due to flooding.

With a well-planned system, water is supplied to many places regularly in a city. This is generally planned by civic authorities in a city. But many times we observe that some amount of water is wasted through leakage of pipe and many other reasons. As we know that proper water management is necessary for the conservation of water. Thus, it is important for civic authorities to take care of these issues while supplying water to our homes.

1.1. Types of Water Management

Water resource management traditionally involves managing water storage and water flows. Clients will need to invest in institutional reinforcement, information management, and (natural and man-made) infrastructure development to enhance water security against this backdrop of rising demand, water scarcity, growing uncertainty, greater extremes, and fragmentation challenges.

Information systems are needed for resource management, uncertain decision taking, system analysis and hydro-meteorological forecasting and warning. Investments in advanced technology to improve efficiency, preserve and protect energy, recycle storm water and wastewater and establish non-conventional water sources should be explored in addition to finding opportunities for improved water storage, including regeneration and recovery of aquifers.

1.2. Water Conservation Methods

While many technological devices are being developed to minimize water wastage, the impact will be greater if each individual contributes to water conservation by minimizing or optimizing the use of groundwater for daily work. Today, water conservation is becoming extremely critical at an individual level.

Each year our water supplies are depleting. Therefore, we cannot produce artificial water and must be reliant on the available water sources on our planet earth. Water shortage is felt all over the world due to population growth and the unsustainable need for water to suit our ever-expanding modern lifestyle. It has given rise to substantial concerns about water conservation.

There are different methods through which water management and conservation can be done, some of them are explained below.

1.2.1. Rainwater harvesting

Rainwater harvesting (RWH) is the collection and storage of rain, rather than allowing it to run off. Rainwater is collected from a roof-like surface and redirected to a tank, cistern, deep pit (well, shaft, or borehole), aquifer, or a reservoir with

percolation. Rainwater harvesting differs from storm water harvesting as the runoff is collected from roofs, rather than creeks, drains, roads, or any other land surfaces. Its uses include watering gardens, livestock, irrigation, domestic use with proper treatment, and domestic heating. The harvested water can also be committed to longer-term storage or groundwater recharge.

Tamil Nadu was the first state to make rainwater harvesting compulsory for every building to avoid groundwater depletion. It gave excellent results within five years, and slowly every state took it as a role model. Since its implementation, Chennai had a 50% rise in water level in five years and the water quality significantly improved. In Rajasthan, rainwater harvesting has traditionally been practiced by the people of the Thar Desert. Many ancient water harvesting systems in Rajasthan have now been revived. At present, in Pune, rainwater harvesting is compulsory for any new housing society to be registered.

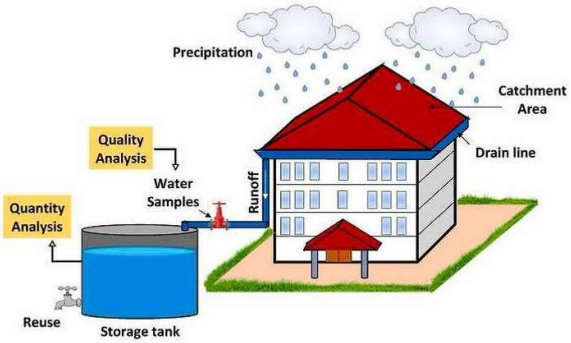


Figure 1a. Typical Rainwater Harvesting system

1.2.2. Groundwater recharge

Groundwater recharge is the enhancement of natural groundwater supplies using man-made conveyances such as infiltration basins, trenches, dams, or injection wells. Aquifer storage and recovery (ASR) is a specific type of groundwater recharge practiced with the purpose of both augmenting groundwater resources and recovering the water in the future for various uses.

Groundwater is recharged naturally by rain and snowmelt and to a smaller extent by surface water (rivers and lakes). Recharge may be impeded somewhat by human activities including paving, development, or logging. These activities can result in loss of topsoil resulting in reduced water infiltration, enhanced surface runoff and reduction in recharge. The use of groundwater, especially for irrigation, may also lower the water tables. Groundwater recharge is an important process for sustainable groundwater management since the volume-rate abstracted from an aquifer in the long term should be less than or equal to the volume-rate that is recharged. Recharge can help move excess salts that accumulate in the root zone to deeper soil layers, or into the groundwater system. Tree roots increase water saturation into groundwater reducing water runoff. Flooding temporarily increases river bed permeability by moving clay soils downstream, and this increases aquifer recharge.

Figure 1b. Groundwater recharge system

1.2.3. Artificial groundwater recharge

Groundwater levels are declining across the country as our withdrawals exceed the rate of aquifers to naturally replenish themselves, called recharge. One method of controlling declining water levels is by using artificial groundwater recharge. Artificial recharge is the practice of increasing the amount of water that enters an aquifer through human-controlled means. For example, groundwater can be artificially recharged by redirecting water across the land surface through canals, infiltration basins, or ponds; adding irrigation furrows or sprinkler systems; or simply injecting water directly into the subsurface through injection wells. Artificial groundwater recharge is becoming increasingly important in India, where the over-pumping of groundwater by farmers has led to underground resources becoming depleted.

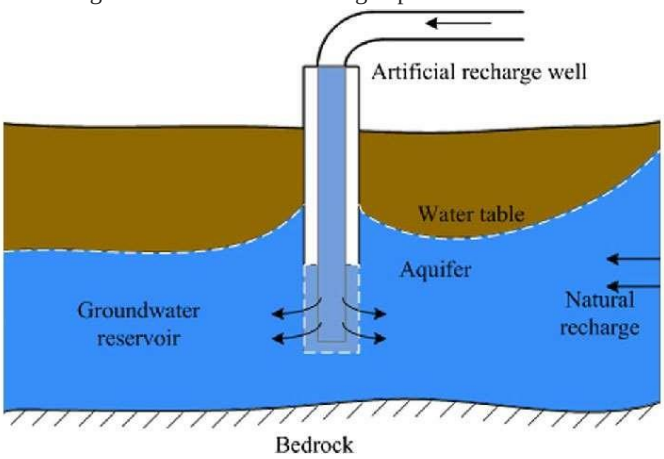


Figure 1c. Artificial groundwater recharge process

1.2.4. Drip irrigation

Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation. Drip irrigation systems distribute water through a network of valves, pipes, tubing, and emitters. Depending on how well designed, installed, maintained, and operated it is, a drip irrigation system can be more efficient than other types of irrigation systems, such as surface irrigation or sprinkler irrigation.

In the drip irrigation process, water and nutrients are delivered across the field in pipes called ‘dripper lines’ featuring smaller units known as ‘drippers’. Each dripper emits drops containing water and fertilizers, resulting in the uniform application of water and nutrients directly to each plant’s root zone, across an entire field. Drip irrigation system delivers water to the crop using a network of mainlines, sub-mains and lateral lines with emission points spaced along their lengths. Each dripper/emitter orifice supplies a measured, precisely controlled uniform application of water, nutrients, and other required growth substances directly into the root zone of the plant.

Figure 1d. Drip Irrigation network system to Conserve Water

1.2.5. Greywater management

Greywater is gently used water from our bathroom sinks, showers, tubs, and washing machines. It is not water that has come into contact with faeces, either from the toilet or from washing diapers. Greywater may contain traces of dirt, food,

grease, hair, and certain household cleaning products. While greywater may look "dirty," it is a safe and even beneficial source of irrigation water in a yard.

The greywater is held briefly in the tank before being discharged to an irrigation or treatment system. The greywater can be diverted either by gravity or by using a pump. The surge tank can be any type of container that is suitable for holding (but not storing) the initial surge of water. The surge tank must be emptied completely each time greywater is dispersed to the irrigation or treatment system – greywater must not sit for extended periods of time in the tank. A gravity system can only be used when there is sufficient fall from the laundry/bathroom drain to the surge tank.

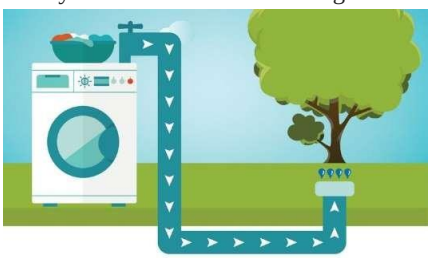


Figure 1e. Illustration of utilization of Greywater System

1.2.6. Sewage water treatment

Sewage treatment is the process of removing contaminants from municipal wastewater, containing mainly household sewage plus some industrial wastewater. Physical, chemical, and biological processes are used to remove contaminants and produce treated wastewater (or treated effluent) that is safe enough for release into the environment. A by-product of sewage treatment is a semi-solid waste or slurry, called sewage sludge. The sludge has to undergo further treatment before being suitable for disposal or application to land.

For most cities, the sewer system will also carry a proportion of industrial effluent to the sewage treatment plant which has usually received pre-treatment at the factories themselves to reduce the pollutant load. If the sewer system is a combined sewer, then it will also carry urban runoff (storm water) to the sewage treatment plant. Sewage water can travel towards treatment plants via piping and in a flow aided by gravity and pumps. The first part of the filtration of sewage typically includes a bar screen to filter solids and large objects which are then collected in dumpsters and disposed of in landfills. Fat and grease are also removed before the primary treatment of sewage.

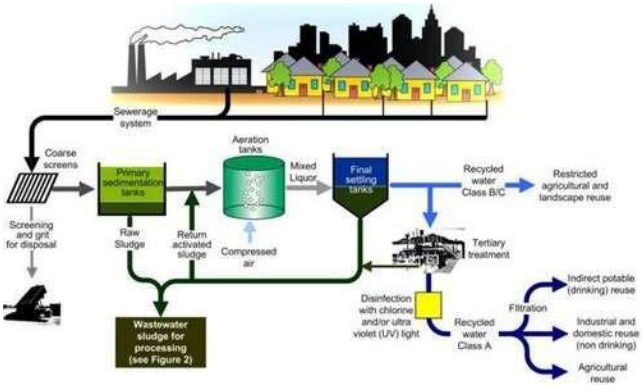


Figure 1f. Workflow in Sewage Treatment Plant

1.2.7. Conjunctive use

Conjunctive use is a catch-phrase for co-ordinated use of surface water and groundwater— literally going with the flow to maximize sufficient yield. Conjunctive use in an irrigation setting is the process of using water from the two different sources for consumptive purposes. It can refer to the practice at the farm level of sourcing water from both a well and from an irrigation delivery canal, or can refer to a strategic approach at the irrigation command level where surface water and groundwater inputsare centrally managed as an input to irrigation systems.

The planned conjunctive use has the potential to offer benefits in terms of economic and social outcomes through significantly increased water use efficiency. It supports greater food and fibre yield per unit of water use, an important consideration within the international policy arena given the critical concerns for food security that prevail in many parts of the world. At the resource level, groundwater pumping for irrigation used in conjunction with surface water provides benefits that increase the water supply or mitigate undesirable fluctuations in the supply and control shallow water table levels and consequent soil salinity.

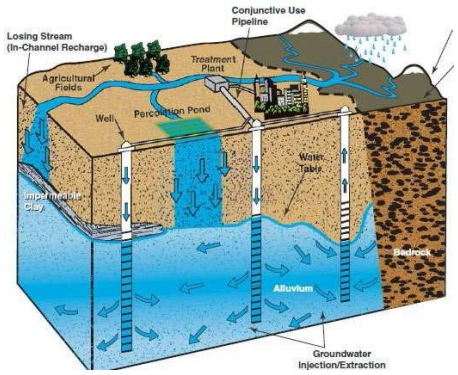


Figure 1g. Evaluating Conjunctive Use through Regional Water Planning

1.2.8. Aquifer storage and recovery

Aquifer storage and recovery (ASR) is the direct injection of surface water supplies such as potable water, reclaimed water (i.e. rainwater), or river water into an aquifer for later recovery and use. The injection and extraction is often done by means of a well. In areas where the rainwater cannot percolate the soil or where it is not capable of percolating it fast enough (i.e. urban areas) and where the rainwater is thus diverted to rivers, rainwater ASR could help to keep the rainwater within an area.ASR is used for municipal, industrial and agricultural purposes.

The objective of AR is to replenish water in an aquifer. Injecting water into AR wells can prevent saltwater intrusion into freshwater aquifers and control land subsidence. In contrast, ASR wells are used to store water in the ground and recover the stored water for drinking water supplies, irrigation, industrial needs, or ecosystem restoration projects. The stored water may be recovered from the same well used for injection or from nearby injection or recovery wells.

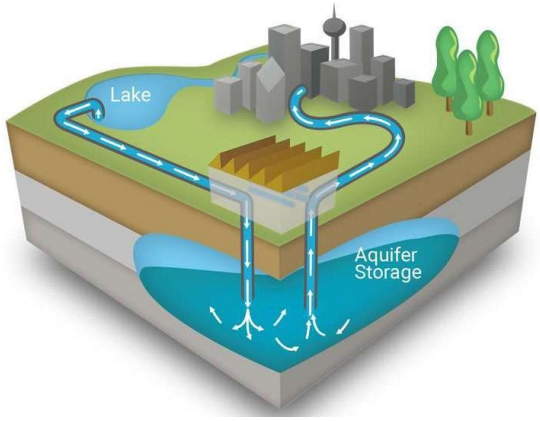


Figure 1h. Schematic of Aquifer storage & recovery

1.2.9. Desalination

Desalination is a process that takes away mineral components from saline water. More generally, desalination refers to the removal of salts and minerals from a target substance, as in soil desalination, which is an issue for agriculture. Saltwater is desalinated to produce water suitable for human consumption or irrigation. The by-product of the desalination process is brine. Desalination is used on many seagoing ships and submarines. Most of the modern interest in desalination is focused on the cost-effective provision of freshwater for human use. Along with recycled wastewater, it is one of the few rainfall-independent water sources.

The process may be used for municipal, industrial, or any commercial uses. Water desalination processes separate dissolved salts and other minerals from water. Feedwater sources may include brackish, seawater, wells, surface (rivers and streams), wastewater, and industrial feed and process waters. Membrane separation requires driving forces including pressure (applied and vapor), electric potential, and concentration to overcome natural osmotic pressures and effectively force water through membrane processes. As such, the technology is energy intensive and research is continually evolving to improve efficiency and reduce energy consumption.

Figure 1i. Desalination Plant

Source: https://www.constrofacilitator.com/different-types-of-water-management-methods/

2. Topic: Flood Control

A flood is an unusually high stage in a river, normally the level at which the river overflows its banks and inundates the adjoining area. The damages caused by floods in terms of loss of life, property and economic loss due to disruption of economic activity are all well known. Thousands of crores of rupees are spent every year in flood control and flood forecasting.

The society and the economy of any country suffer in many ways after a flood with the loss of lives, vegetation, properties and infrastructure, which means there will be fewer people on the labor force, less agriculture available for locals and for exporting and less businesses to contribute to the country's economy development. There will be mass displacement of people, many of whom may be left homeless and jobless. In order to fill this gap, the government will have to spend at a higher level.The country may have to look for international assistance to supply food and materials to clean and rebuild its infrastructure.While some countries will support voluntarily, other will charge for their efforts, putting the assisted country in debt and at aneconomic loss.

2.1. Causes and consequences of floods

Flooding may be caused by many factors such as intense rainfall, strong winds over water, unusual high tides, tsunamis or failure of dams, elevation of retention pond levels or other structures that contain water. Periodic flooding occurs in many rivers, forming a surrounding region known as an alluvial plain. During periods of rain or snow, some of the water is retained in ponds or soil, others are absorbed by grass and vegetation, some evaporate and the rest travels over the land as surface runoff. Flooding occurs when lakes, riverbeds, soil and vegetation cannot absorb all the water. Water then escapes from land in quantities that cannot be transported into the channels of streams or retained in natural ponds, lakes, and man-made reservoirs. Rapid flooding, with little or no advance warning, is called a sudden flood. Sudden floods usually result from heavy rains in a relatively small area, or if the area was already saturated with previous precipitation. Severe winds over water are another cause of flooding. Even when the rain is relatively light, the banks of lakes and bays can be flooded as a result of strong winds such as during hurricanes that blow water to the coastal areas. Another cause is the unusual high tides that occur, sometimes in coastal areas when they are flooded by unusually high tides, especially when composed of strong winds and storms.

Flooding causes many impacts. They damage property and endanger the lives of humans and other living things. Rapid water runoff causes soil erosion and concomitant deposition of sediment at various locations, as well as fish spawning sites and other wildlife habitats, which may become polluted or completely destroyed. Some high and prolonged floods can compromise vehicle traffic in areas that do not have elevated roads. Flooding can interfere with drainage and economic land use, as well as with agriculture. Structural damage can occur in bridge pillars, sewage systems and other structures in the area of floods. Water navigation and hydroelectric power are often hampered. Financial losses due to floods are typically of millions of dollars each year. According to latest research, floods or sudden floods are among the most frequent natural disasters that cause greater economic losses and difficulties to human activity. About 90% of the damage caused by all natural disasters (droughts excluded) is caused by floods and associated water flows. The floods are responsible for the death of almost twice the number of people than are tornadoes and hurricanes put together. An important impact resulting from the sudden flood is the landslide. A landslide is a geological and climatologically phenomenon that includes a broad spectrum of soil movements, such as rock falls, landslide in depth and surface streams of debris.

2.2. Flood control and flood management

2.2.1. Flood control:

Flood control refers to all methods used to reduce or prevent the damaging effects of flood waters. Some of the common techniques used for flood control are the installation of rock beams, rock rip-raps, sand bags, maintenance of normal slopes with vegetation or application of soil cements on steeper slopes and construction or expansion of drainage. Other methods include dykes, dams, retention basins or detention.

The engineering works that can prevent and mitigate the effects of floods are as follows:

1) On highways, the implantation of steel pipes should take water by gravity away from the road from catchment basins;

2) The severe flooding problems in a city that paved much of its soil would be alleviated in part by the construction of great swimming pools that are large underground water tanks to store the waters;

3) Mandatory placement of permeable drainage floors in huge courtyards of parking lots in malls, supermarkets and cinemas, to allow the water infiltration in part of the ground, being the same for monuments and spaces around buildings;

4) using drains and gutters around all houses to divert rainwater to a reservoir or disposal area;

5) Maintenance, whenever possible, of some green areas so that the water is reabsorbed by the soil;

6) Rectification of rivers and streams, construction of dams and canals in large rivers that extend their containment basins; and

7) Implementation of a civil defense system that should be able to at least warn people and have a scheme to remove them from homes in time with some belongings and accommodate them.

Caring to avoid flooding in urban areas is, as follows:

1) keeping streets and sidewalks always clean;

2) cleaning and unclogging manhole and storm drain;

3) keeping in the houses the channels and other channels of rainfall free of branches and leaves of trees to avoid clogging and, consequently, return of water;

4) putting garbage bags on the sidewalks only near the time the garbage collection truck will come, preventing them from being drawn into the manhole when it rains;

5) having a drain pump on hand if flooding cannot be avoided; and

6) using Dutch and British flood proof technology as a floating amphibian house that allows buildings to float in the same way as a boat.

Hydrological experts recommend that, in order to avoid flooding in urban areas, the following measures should be adopted:

1) Combating erosion by minimizing sedimentation of natural drainage and built up through rigorous and extensive soil erosion control and irregular disposition of urban garbage and construction rubble , as well as the expansion of the river gutters;

2) Combating waterproofing with the creation of domestic and business reservoirs, as well as the expansion of green areas;

3) Forbidding traffic on high traffic avenues when nearby rivers overflow;

4) Implantation of avenues covered by vegetation that, in cases of overflowing rivers or streams, water would be absorbed by the pavement free soil;

5) Constructing great swimming pools to receive rainwater and mini swimming pools in houses and buildings;

6) Investing in small and large streams of the urban center to support the increase of water and act as containment barriers;

7) Review of occupied areas – continuous planning and land-use planning; and

8) Action and planning – preparation of a plan to deal with the occurrence of floods as well as extreme climatic variations, and construction of reservoirs capable of storing billions of cubic meters of water and their use for non-potable purposes.

2.2.2. Flood management:

In order to deal with flood risks, it is essential that prevention and precaution measures are adopted to avoid catastrophic events. The Preliminary Environmental Impact Assessment of Floods is an important instrument for the formulation of civil defense plans as it is used to assess, predict and prevent further economic and social damages resulting from floods. It should be noted that preventive or precautionary measures should be based on risk management policies and, above all, be present in the proposals and actions of the Civil Defense in dealing with the floods. Prevention and precaution are two prudence aspects that are put in front of situations when there is the possibility of damage. The economic calculation should serve as a basis for decisions related to prevention and precaution. In deciding on the economic alternatives to be adopted, one factor that greatly complicates the solution of a problem is uncertainty. Another complicating factor is insufficient information. Uncertainty can be minimized and insufficient information can be remedied by the constitution of what is called Big Data. In information technology, the term Big Data refers to a large set of stored data. It is said that Big Data is based on 5 factors: velocity, volume, variety, veracity and value. It's necessary to take the right information, to the right people, at the right time to make decisions.

This requires asking the right questions and analyzing the data knowingly to understand the flood dynamics. Big Data enables the analysis of a huge amount of information to show patterns and correlations, in many cases totally unknown. Big Data opens up a wider range of possibilities that can turn into paths to innovation. It should be noted that decision-making is a process of analysis and choice of several alternatives available, of the course of action to be followed. The decision-making process consists of 6 steps:

1) Perception of the situation;

2) Analysis and definition of the problem;

3) Definition of objectives;

4) Search for solution alternatives;

5) Evaluation and comparison of these alternatives;

6) Choice of the most appropriate alternative.

2.3. Floods in India

Floods are recurrent phenomena in India. Due to different climatic and rainfall patterns in different regions, it has been the experience that, while some parts are suffering devastating floods, another part is suffering drought at the same time. With the increase in population and development activity, there has been a tendency to occupy the floodplains, which has resulted in damage of a more serious nature over the years. Often, because of the varying rainfall distribution, areas which are not traditionally prone to floods also experience severe inundation. Thus, floods are the single most frequent disaster faced by the country. Some parts of the country, mainly coastal areas of Andhra Pradesh, Orissa, Tamil Nadu and West Bengal, experience cyclones, which are often accompanied by heavy rainfall leading to flooding.

2.3.1. Damage from floods

More significant than the loss of life and damage to property is the sense of insecurity and fear in the minds of people living in the floodplains. The after-effects of flood, such as the suffering of survivors, spread of disease, non-availability of essential commodities and medicines and loss of dwellings, make floods the most feared of the natural disasters faced by humankind. Heavy flood damage was inflicted during the monsoon of 1955, 1971, 1973, 1977, 1978, 1980, 1984, 1988, 1989, 1998, 2001 and 2004. Highlights of the damage are given below:

Table 2. Statistics of damage due to Floods in India

	Maximum	**Average**
Area affected	17.5 million ha (1978)	7.63 million ha
Crop area affected	10.15 million ha (1988)	3.56 million ha
Population affected	70.45 million (1978)	32.92 Million
Houses damaged	3 507 542 (1978)	1 234 616
Heads of cattle lost	618 248 (1979)	91 242
Human lives lost	1 1316 (1977)	1 560
Damage to public utilities	US$ 705 million (1998)	US$ 126 million
Total damage	US$ 1 255 million (1998)	US$ 307 million

Figure 2a. Map showing flood prone zone in India

2.3.2. Approach to flood management

Approaches to dealing with floods may be any one or a combination of the following available options:

- Attempts to modify the flood
- Attempts to modify the susceptibility to flood damage
- Attempts to modify the loss burden
- Bearing the loss.

The main thrust of the flood protection programs undertaken in India so far has been an attempt to modify the flood in the form of physical (structural) measures to prevent the floodwaters from reaching potential damage centres and modify susceptibility to flood damage through early warning systems.

Structural measures

The following structural measures are generally adopted for flood protection:

- Embankments, flood walls, sea walls
- Dams and reservoirs
- Natural detention basins
- Channel improvement
- Drainage improvement Diversion of flood waters.

Non-structural measures

Non-structural measures include:

- Flood forecasting and warning centres
- Floodplain zoning
- Flood fighting
- Flood proofing
- Flood insurance.

2.4. Best Practices

It is necessary to distinguish between different kinds of flooding and the environmental conditions that contribute to the problem. For instance, there are significant differences between on the one hand sudden flooding in upstream or headwater areas where mitigating risk involves a wide range of innovative small-scale solutions and on the other hand low land flooding where warning periods and the duration of flood events are longer and large-scale measure have to be taken. Therefore, the effectiveness of the best practices described depends on among other hydrological and environmental circumstances.

- Integrated river basin approach
- Public awareness, public participation and insurance
- Research, education and exchange of knowledge
- Retention of water and non-structural measures
- Land use, zoning and risk assessment
- Structural measures and their impact
- Flood emergency
- Prevention of pollution

Source:
https://www.heraldopenaccess.us/article_pdf/15/flood-control-and-its-management.pdf
https://public.wmo.int/en/bulletin/flood-and-drought-management-through-water-resources-development-india
https://ec.europa.eu/environment/water/flood_risk/pdf/flooding_bestpractice.pdf

3. Topic: Multipurpose Water Projects

Dams were traditionally built to impound rivers and rainwater that could be used later to irrigate agricultural fields. Today, dams are built not just for irrigation but for:

1. Electricity generation
2. Water supply for domestic and industrial uses
3. Flood control
4. Recreation
5. Inland navigation
6. Fish breeding etc.

Hence dams are now referred to as multipurpose projects where the many uses of the impounded water are integrated with one another. Multipurpose river valley projects basically refer to large dams which serve various purposes in addition to impounding the water of a river. The water that is blocked is used for domestic purposes, industries, irrigation, navigation as well as to generate hydroelectric power.

Multi-purpose dams are typically used to combine hydropower through water turbines and storage of water for irrigation or water supply. A feature with a flood-control function to prevent rise in the level of rivers is also common in flood-prone areas. Some examples of multipurpose dams on the river valley are mentioned below:

1. Beas Project is a joint venture by the governments of Punjab, Haryana and Rajasthan to create a multi-purpose dam for the development of their states. It consists of two main units: Beas-Sutlej Link and the Beast Dam at Pong. The project links the Beas river and the Sutlej rivers in Punjab along a 38.4 km long valley of hills. The waters from Beas were poured into the magnificent Sutlej river in July of 1977. It was the first-ever, man-made confluence between two major rivers in Himachal. In the Satluj-Beas river basin, the Bhakra Nangal project water is being used both for hydel power production and irrigation.

2. Chambal Valley Project is also a joint venture undertaken by the governments of Rajasthan and Madhya Pradesh. It is made on the Rana Pratap Dam at Bhata which is 48 km from Kotah. It was inaugurated on Feb 9 in 1970. The project comprises construction of two more dams that are: the Gandhi Sagar Dam present in Madhya Pradesh and the Jawahar Sagar dam present in Rajasthan.

3. The Hirakud project in the Mahanadi basin integrates conservation of water with flood control.

Multipurpose projects, launched after independence with their integrated water resources management approach, were thought of as the vehicle that would lead the nation to development and progress. But in the recent years, multipurpose projects and large dams have come under great scrutiny for a variety of reasons:

- Regulating and damming of rivers affects their natural flow causing poor sediment flow and excessive sedimentation at the bottom of the reservoir, resulting in rockier stream beds and poorer habitats for the rivers' aquatic life.
- Dams also fragment rivers making it difficult for the aquatic fauna to migrate, especially for spawning.
- The reservoirs that are created on floodplains also submerge the existing vegetation and soil leading to its decomposition over a period of time.
- In geologically unstable areas, development of large dams can destabilise the land. The 2013 Uttarakhand Floods triggered a debate on whether the hydropower projects operational in Uttarakhand were responsible for the floods that killed more than 1000 people.
- Inter-state water disputes are also becoming common with regard to sharing the costs and benefits of the multipurpose projects.

Table 3. List of Important River Water Projects in India

Project	**River**	**Related State**
Bansagar Project	Son	Bihar, Uttar Pradesh, Madhya Pradesh
Bargi Project	Bargi	Madhya Pradesh
Beas Project	Beas	Haryana, Punjab, Rajasthan
Bhadra Project	Bhadra	Karnataka
Bhakhra Nangal Project	Sutlej	Punjab, Himachal Pradesh , Haryana, Rajasthan
Bheema Project	Pawana	Maharashtra
Chambal Project	Chambal	Rajasthan, Madhya Pradesh
Damodar Ghati Project	Damodar	Jharkhand, West Bengal
Dulhasti Project	Chinab	Jammu & Kashmir
Durga Barrage Project	Damodar	West Bengal, Jharkhand
Farakka Project	Ganga, Bhagirathi	West Bengal
Gandak Project	Gandaki	Bihar, Uttar Pradesh
Ganga Sagar Project	Chambal	Madhya Pradesh
Ghatprabha Project	Ghatprabha	Karnataka
Girna Project	Girna	Maharashtra
Hansdev Bango Project	Hansdev	Madhya Pradesh
Hidkal Project	Ghatprabha	Karnataka
Hirakud Project	Mahanadi	Orissa
Idduki Project	Periyar	Kerala
Indira Gandhi Canal Project	Satlaj	Rajasthan, Punjab, Haryana
Jawahar Sagar Project	Chambal	Rajasthan
Jayakwadi Project	Godawari	Maharashtra

Kakrapara Project	Tapti	Gujrat
Kangsawati Project	Kangsawati	West Bengal
Kol Dam Project	Sutlaj	Himachal Pradesh
Kosi Project	Kosi	Bihar & Nepal
Koyana Project	Koyana	Maharashtra
Krishna Project	Krishna	Karnataka
Kunda Project	Kunda	Tamilnadu
Let Bank Ghaghra Canal	Ganaga	Uttar Pradesh
Madhya Ganaga Canal	Ganaga	Uttar Pradesh
Mahanadi Delta Project	Mahanadi	Odisha
Malprabha Project	Malprabha	Karnataka
Mandi Project	Vyas	Himachal Pradesh
Matatilla Project	Betwa	Uttar Pradesh, Madhya Pradesh
Mayurakshi Project	Mayurakshi	West Bengal
Minimato Bango Hasdeo Project	Hasdeo Bango river	Madhya Pradesh
Muchkund Project	Muchkund	Odisha, Andhra Pradesh
Nagarjunsagar Project	Krishna	Andhra Pradesh
Nagpur Power Project	Koradi	Maharashtra
Narmada Sagar Project	Narmada	Madhya Pradesh, Gujarat
Nathpa Jhakri Project	Sutlaj	Himachal Pradesh
Panam Project	Panam	Gujarat
Panama Project	Panama	Gujarat
Panchet Project	Damodar	Jharkhand, West Bengal
Pong Project	Beas	Punjab
Poochampad Project	Godawari	Andhra Pradesh
Purna Project	Purna	Maharashtra
Rajasthan Canal Project	Sutlej, Vyas, Ravi	Rajasthan, Punjab, Haryana
Ramganga Project	Ramganga	Uttar Pradesh
Rana Pratap Sagar Project	Chambal	Rajsthan
Ranjeet Sagar Project	Ravi	Punjab
Rihand Project	Rihand	Uttar Pradesh
Salal Project	Chenab	Jammu & Kashmir
Sardar Sarovar Project	Narmada	Madhya Pradesh, Maharashtra, Rajasthan
Sarhind Project	Sutlaj	Haryana

Sharawati Project	Sharawati	Karnataka
Sharda Project	Sharda, Gomti	Uttar Pradesh
Shivsamundram Project	Kaveri	Karnataka
Sutlaj Project	Chinab	Jammu & Kashmir
Tawa Project	Tawa	Madhya Pradesh
Tehri Dam Project	Bhagirathi	Uttarakhand
Tilaiya Project	Barakar	Jharkhand
Tulbul Project	Chinab	Jammu & Kashmir
Tungbhadra Project	Tungbhadra	Andhra Pradesh, Karnataka
Ukai Project	Tapti	Gujarat
Upper Penganga Project	Penanga	Maharashtra
Uri Power Project	Jhelum	Jammu & Kashmir
Vyas Project	Vyas	Rajasthan, Punjab, Haryana, Himachal Pradesh

4. Topic: Water Sharing Techniques

The dawn of 21st century is a gloomy picture for future generations of India because of increasing water scarcity, which is often fabricating threats of water conflicts. Water is a critical shared resource, and its flow is not restricted to any political boundaries. This necessitates peaceful sharing of water resources both within and among countries. Sharing water is a complex task in most cases in the present era of water conflicts. India, which relished its past fame as water prosperous country, todayis moving towards becoming a water stressed nation due to rapid population upsurges and unequal distribution. The demand for water has tripled at a time when the supply of water services is inefficient with socio-economic diversities. Poverty has already become a constant threat for the economy, and water should not add to it. The development policies in India includingwater resources tend to give primacy to economic cost, disregarding environmental and social cost. This has aggravated tensions further. Considering the existing water-sharing treaties and arrangement with neighbors and suggesting sustainable measures to prevent conflicts and tackle water scarcity is a big challenge for researchers and Indian policy makers today. This is mainly because along with India its neighbors also share the common problems of poverty, population rise, and water stress. A peaceful sharing thus becomes complex many times and hence conflicts in many cases become obvious phenomena.
Currently, our country is trying to solve i) Disputes related to Inter-State River Water Sharing and ii) River linking

i) Disputes on Inter-State River Water Sharing

The Interstate River Water Disputes Act, 1956 (IRWD Act) is an Act of the Parliament of India enacted under Article 262 of Constitution of India on the eve of reorganization of states on linguistic basis to resolve the water disputes that would arise in the use, control and distribution of an interstate river or river valley. Article 262 of the Indian Constitution provides arole for the Central government in adjudicating conflicts surrounding inter-state rivers that arise among the state/regional governments. This Act further has undergone amendments subsequently and its most recent amendment took place in the year 2002.

ii) River linking

River Linking is a project of linking two or more rivers by creating a network of manually created reservoirs and canals, and providing land areas that otherwise does not have river water access and reducing the flow of water to sea using this means. It is based on the assumptions that surplus water in some rivers can be diverted to deficit rivers by creating a network of canals to interconnect the rivers.

Table 4. Inter-State River Water Sharing Disputes

Major Inter-State River Disputes	
River (s)	**States**
Ravi and Beas	Punjab, Haryana, Rajasthan
Narmada	Madhya Pradesh, Gujarat, Maharashtra, Rajasthan
Krishna	Maharashtra, Andhra Pradesh, Karnataka, Telangana
Vamsadhara	Andhra Pradesh & Odisha
Cauvery	Kerala, Karnataka, Tamil Nadu and Puducherry
Godavari	Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Odisha
Mahanadi	Chhattisgarh, Odisha
Mahadayi	Goa, Maharashtra, Karnataka
Periyar	Tamil Nadu, Kerala

4.1. Benefits of River linking:

Irrigation- By linking the rivers, vast amount of land areas which will not otherwise be irrigated and are unusable for agriculture become fertile.[2]

Flood prevention- During heavy rainy seasons some areas can experience heavy floods while other areas might be experiencing drought like situations. With network of rivers this problem can be greatly avoided by channeling excess water to areas that are not experiencing a flood or are dry.

Generation of electricity- With new canals built, feasibility of new dams to generate hydroelectric power becomes a possibility.

Transportation- Newly created network of canals opens up new routes and ways of water navigation, which is generally more efficient and cheaper compared to road transport.

4.2. National River Linking Project in India

The National River Linking Project (NRLP) is designed to ease water shortages in western and southern India while mitigating the impacts of recurrent floods in the eastern parts of the Ganga basin. The NRLP, if and when implemented, will be one of the biggest inter basin water transfer projects in the world.

4.2.1. Issues and Concerns

Ecological issues- One of the major concerns is that rivers change their course in 70–100 years and thus once they are linked, future change of course could create huge practical problems for the project.

Aqua life- A number of leading environmentalists are of the opinion that the project could be an ecological disaster. There would be a decrease in downstream flows resulting in reduction of fresh water inflows into the seas seriously jeopardizing aquatic life.

Deforestation- Creation of canals would need large areas of land resulting in large scale deforestation in certain areas.

Areas getting submerged- Possibility of new dams comes with the threat of large otherwise habitable or reserved land getting submerged under water or surface water.

Displacement of people- As large strips of land might have to be converted to canals, a considerable population living in these areas must need to be rehabilitated to new areas.

Dirtying of clean water- As the rivers interlink, rivers with dirty water will get connected to rivers with clean water, hence dirtying the clean water.

END

3D Printing

3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created.

There are two methods of manufacturing, Additive manufacturing and Subtractive manufacturing. One such process is 3D printing. Which is the process involving making of 3D elements using a design file. 3D printing is one of the additive manufacturing techniques (AM). As opposed to subtractive manufacturing, 3D objectsare created by successively depositing material in layers.

AM technology was first developed in 1980s and is being successfully applied to various industries.

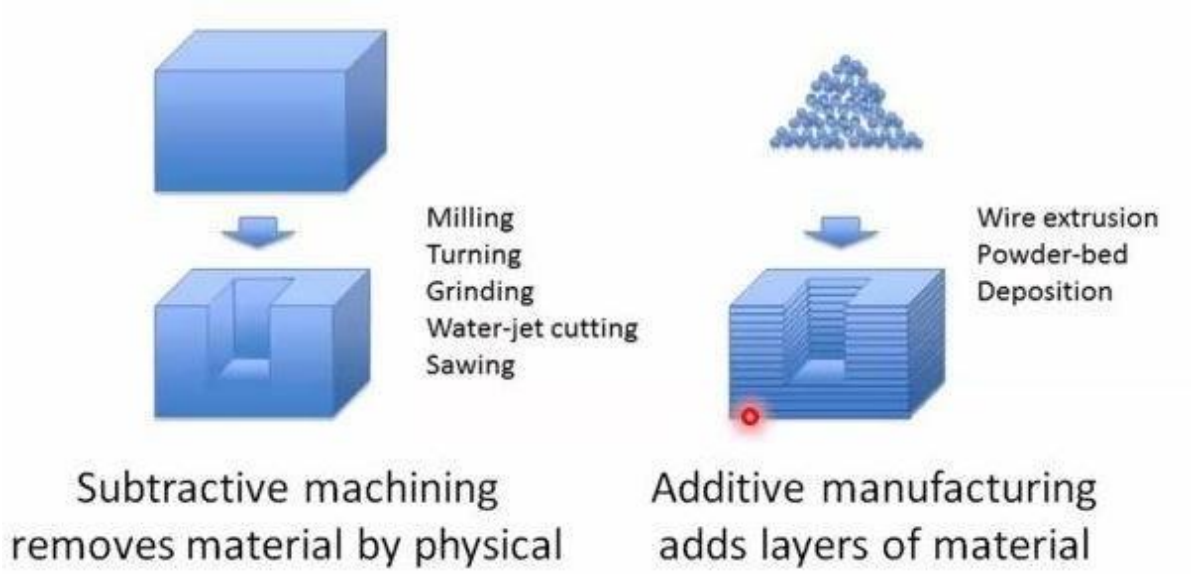


Fig 1: subtractive and additive manufacturing.

This technology of AM was first introduced in the year 1984 by Charles Hull. He was instrumental in the manufacture and design of the first 3D Printer that we have heard. He also introduced .STL format into the world of 3D Printing. STL stands for Stereo Lithography which is the only format that the 3D slicing software recognizes. The first known 3D print from a STL file is said to be printer by Hideo Kodama.

After this a lot of research was conducted and a lot of new 3D printers are introduced, with advanced features making them more efficient. 3D printers with dual extrusion, printer that can print various materials like wood, steel, PLA, ABS etc. In 3D printing first a 3 Dimensional design is created which is solid. This is then exported into a STL file. This STL file is then cut into slices of layers using the slicing software 3D printing was first used to make prototypes in the 20th century. These prototypes used to cost a huge sum when in manufacturing and with 3D printing it became easy toprint prototypes and also use them in industries automobile industries. 3D Printing hasa huge advantage in reducing cost of construction comparing to conventional construction processes, and hence there is a need to understand more in order to successfully implement in construction industry.

Some of the applications are 1) Decreasing cost by eliminating or reducing expensive formwork. 2) Decreased injury rates, as a machine was doing tough jobs 3) Increase in jobs 4) Reduction of construction in-situ time. 5) Reducing mistakes by highly accurate formation of materials 6) giving freedom to architects to design extraordinarystructures with sophisticated designs. 7) Reduce- reuse and recycle is followed for a sustainable construction.

1.1 METHODOLOGY OF 3D PRINTING

In 3D printing first a 3 Dimensional design is created which is solid as seen in the first image of Fig 2. This is then exported into a STL file. This STL file is then cut into slices or layers using the slicing software which is saved in the .GCODE format, as seen in image 2 from left in Fig 2. This GCODE is the machine understandable language that enables the extruder in a 3D printer to move in 3 Axis, namely X-Y-Z. And after repetitive printing in X-Y axis and moving up in the Z axis a complete design is made.

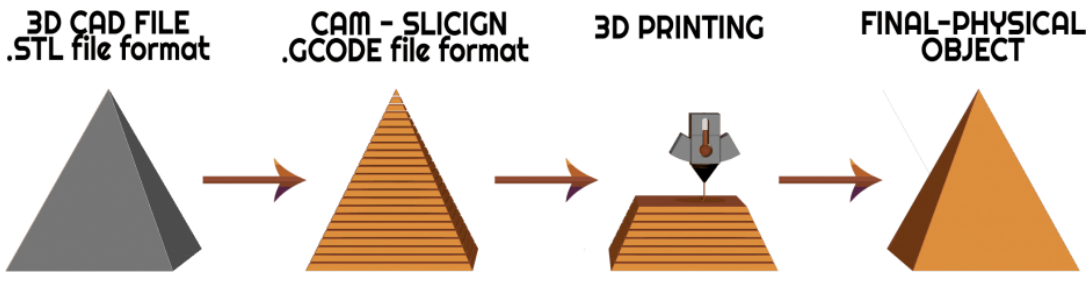


Fig 2: Process of 3D printing

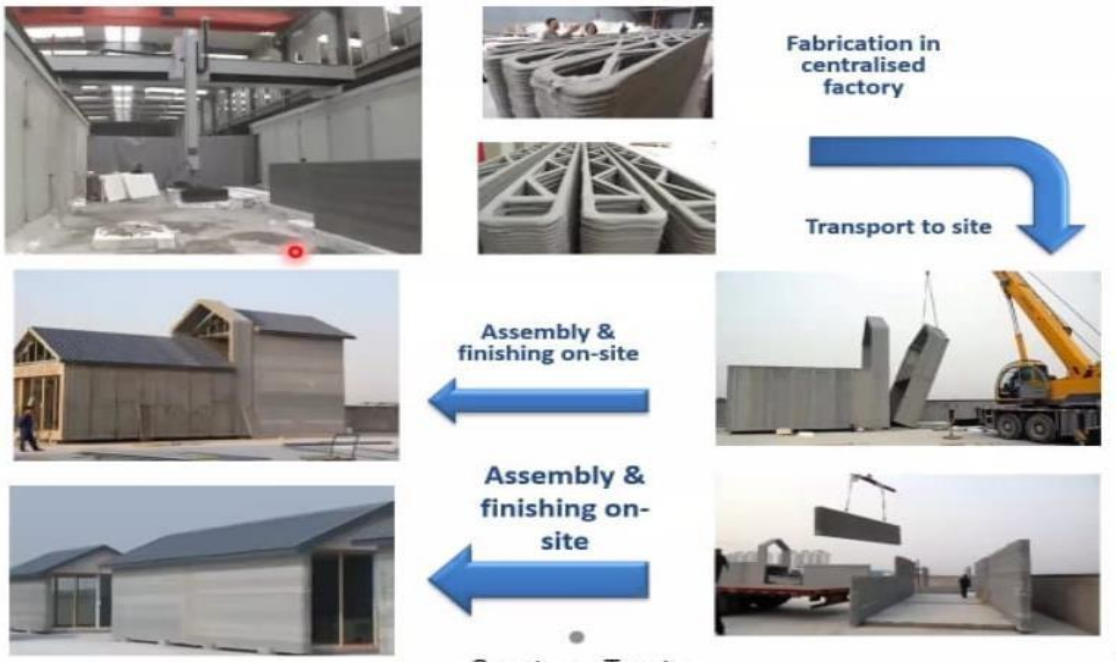


Fig 3: Process of 3D printing

1.2 EXAMPLES OF 3D PRINTED STRUCTURES

1.2.1 3D PRINTED OFFICE IN DUBAI

A office was 3D Printed in Dubai as seen in the fig 4 and 5 below. This office was printed to be occupied by National Committee of UAE. This 3D printed structure is officially completely functional with electricity, water, good ventilation and a garden. This is a precast type of project which was printed in a facility in china and then erected at site in Dubai. There was a reduction in labor cost by 65% percent and a reduction in construction waste by approximately 45% which is a huge advantage of 3D printing. The project ultimately reduced labor costs by 50 % to 80% and construction waste by 30% to 60%.

Fig 4: Side view.

Fig 5: Front view.

1.2.2 3D PRINTED HOUSE

A 3D printed house with a 400sqft built up area which was designed completely from scratch. This is popularly named as Apis Cor and I located in Russia. Fig 6 and Fig 7 show the structure.

This structure 3D printed using a robot with single movable arm. The house can be occupied which has all the features such as lighting, plumbing and a good finish. This house is said to havebeen printed in a record time of 24hrs. The structure was printed for a cost of approximately 7 lakhs rupees. The structure is painted and also fixed with fixtures such as door and window.

Fig 6: Front view of Apis Cor House in Russia.

1.3 ADVANTAGES OF 3D PRINTING

1. One of the biggest advantages of concrete 3d printing is the **reduced time** that itrequires. It can be used for building disaster relief shelters in a much reduced amount of time.
2. Manual labor is not required hence reducing the cost as well as the chances of accidents and injuries.
3. Better for sustainability as recycled concrete can be used as construction material
4. Large components can be easily created.

5. Biggest advantage, any architectural designs involving complexities can be constructed easily.
6. Highest degree of precision is obtained.
7. Reduction of cost by eliminating expensive formwork.
8. Reduction of injury rates by eliminating dangerous jobs (i.e. working at heights)
9. Creation of high end technology jobs.
10. Minimizing the chance of errors by highly precise material deposition.
11. Accurate analysis of scaled models (structures) experimentally before construction.

1.4 APPLICATIONS OF 3D PRINTING

1. 3D Printing has its application in rapid prototyping. 3D printing has reduced the cost of making prototypes and testing them. Using 3D printing structures small enough to provide shelters during a natural disaster can be printed in a time frame of 3hrs to 6 hrs. the added advantage is that it can be done with minimal human intervention.
2. With further improvements in 3D printing, more and different materials are being printed such as cement, steel, wood etc. Dual extrusion printers are available which can 3D print two types of materials at a time.
3. 3D printing is also used in printing additional requirements for a house such as aesthetic detailing and interior designing related things.
4. The strength of a 3D printed concrete is higher than the regular concrete as it mostly uses fibres for reinforcement.
5. Current research is going on to 3D print structures on moon using lunar soil by the European space agency.

Fig 7: Contour Crafting Process Apis Cor House.

RAMAIAH
Institute of Technology

BASICIS OF CIVIL ENGINEERING & MECHANICS

Course code:CV14/CV24

Credits:3:0:0

Topics Covered

Force- Definition, classification of force systems, composition and resolution of forces.

Couple, Moment of Couple

MECHANICS

Mechanics

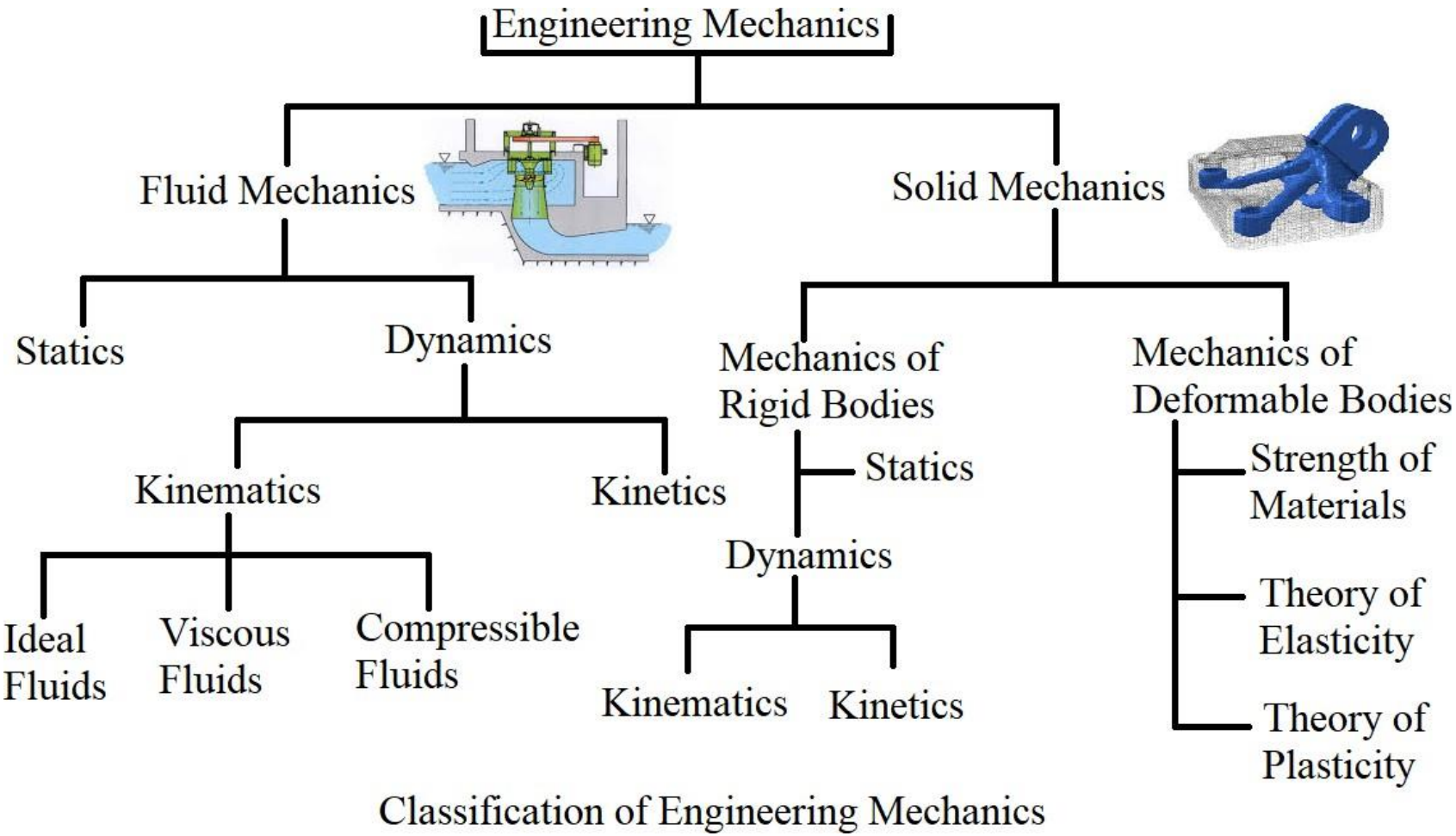
A branch of physical science that deals with energy and forces and their effect on bodies.

Engineering Mechanics

It is the application of mechanics to the solution of Engineering problems. Broadly classified into three types

1. Mechanics of Rigid Bodies- Statics and Dynamics
2. Mechanics of deformable bodies- SOM, TOP, TOE
3. Mechanics of fluids-Compressible and incompressible

MECHANICS



Classification of Engineering Mechanics

- Particle: A body of infinitely small volume whose mass can be neglected, is called a particle.
- Rigid body: A rigid body is one in which the positions of the constituent particles do not change under the application of external forces, such as the position of particles shown inFigure 1.

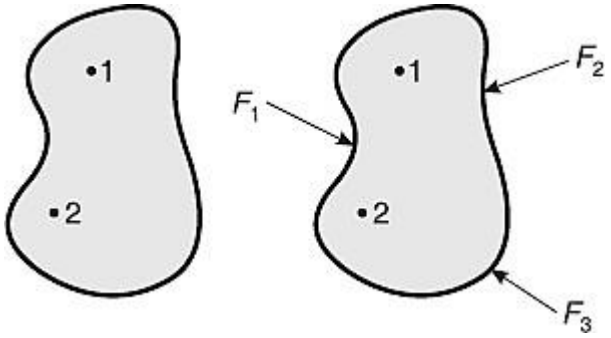


Figure. 1 Rigid body

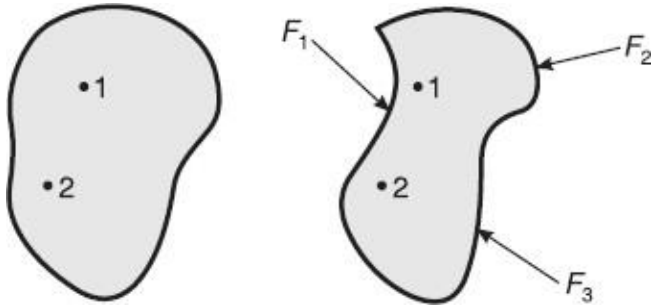


Figure. 2 Deformable body

- Continuum: A continuous distribution of molecules in a body without intermolecular space is called continuum.
- Mass: The total amount of matter present in a body is known as it's mass. The unit of mass is kg(kilogram)
- Weight: The force that gravitation exerts upon a body, equal to the mass of the body times the local acceleration of gravity W=mg

Elements of a Force or Characteristics of a Force

A force can be identified by its four characteristics:

(i) Magnitude: The length of the vector represents the magnitude of force

(ii) Direction: The direction of a force can be represented by an arrowhead.

(iii) Line of action: It is the line along which the force acts.

(iv) Point of application: It is the point at which the force acts.

Force system:

If two or more forces are acting on a body or a particle, then it is said to be a force system, such as that shown in Figure 3.

The types of force system are:

1. Coplanar force system
2. Non-coplanar force system
3. Collinear force system.

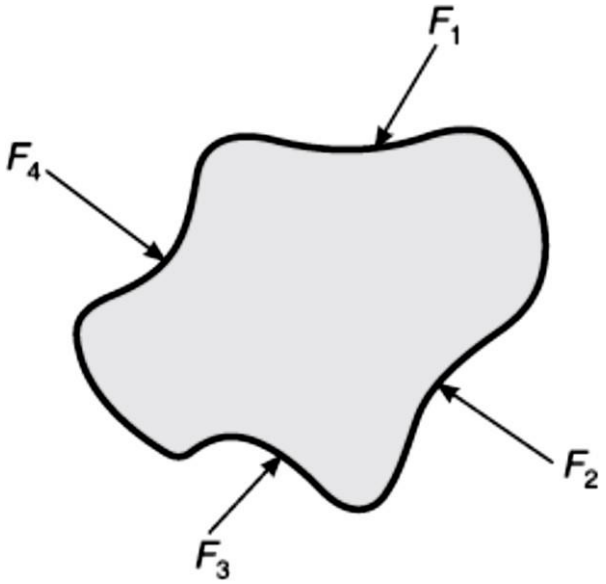


Figure.3 Force system

Coplanar force system

If two or more forces are acting in a single plane, then it is said to be a coplanar force system. The types of coplanar force system are:

(i) Coplanar concurrent force system

(ii) Coplanar non-concurrent force system

(iii) Coplanar parallel force system.

(i) Coplanar concurrent force system:

If two or more forces are acting in a single plane and their lines of action pass through a single point, then it is said to be a coplanar concurrent force system. Shown in Figure.4.

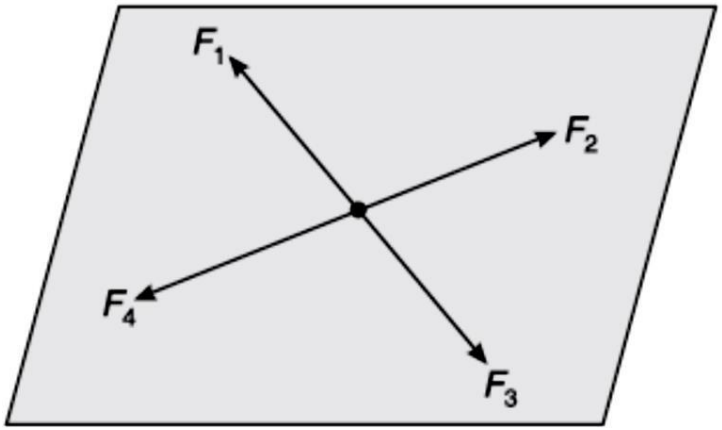


Figure.4 Coplanar concurrent force system.

(ii) Coplanar non-concurrent force system

If two or more forces are acting in a single plane and their lines of action do not meet at a common point, then the forces constitute a coplanar non-concurrent force system. Shown in Figure.5.

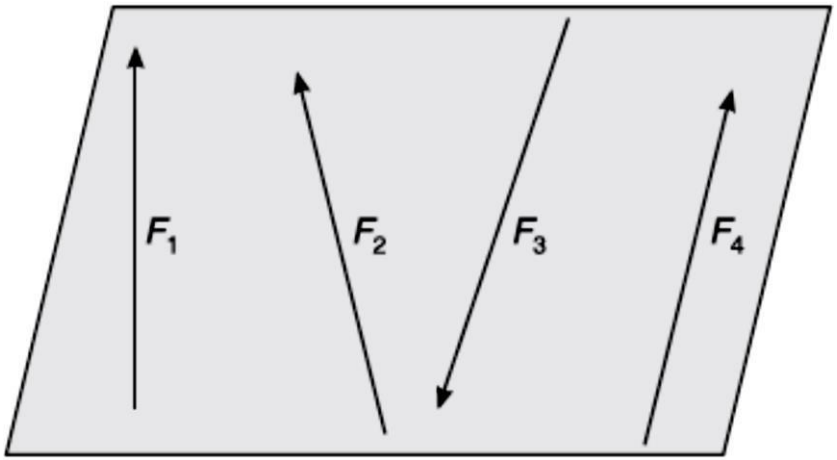


Figure.5 Coplanar non concurrent force system.

(iii) Coplanar parallel force system.

If two or more forces are acting in a single plane with their lines of action parallel to one another, then it is said to be a coplanar parallel force system.

The coplanar parallel force system is of two types:

(i) Like parallel force system: All the forces act parallel to one another and are in the same direction, as shown in Figure 6.

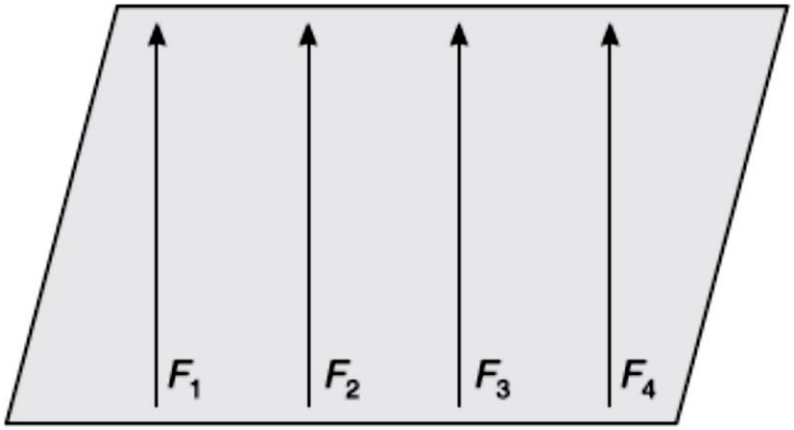


Figure.6 Like parallel force system

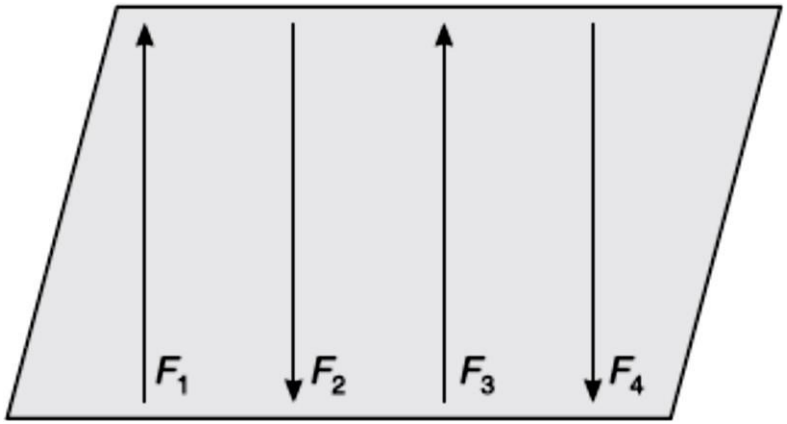


Figure.7 Unlike parallel force system

Non-coplanar force system

If two or more forces are acting in different planes, the forces constitute a non-coplanar force system. Such a system of forces can be,

(i) Non-coplanar concurrent force system

(ii) Non-coplanar non-concurrent force system

(iii) Non-coplanar parallel force system.

(i) Non-coplanar concurrent force system

If a system has two or more forces acting on different planes but pass through the same point, then it is said to be a non-coplanar concurrent force system. As shown Figure.8.

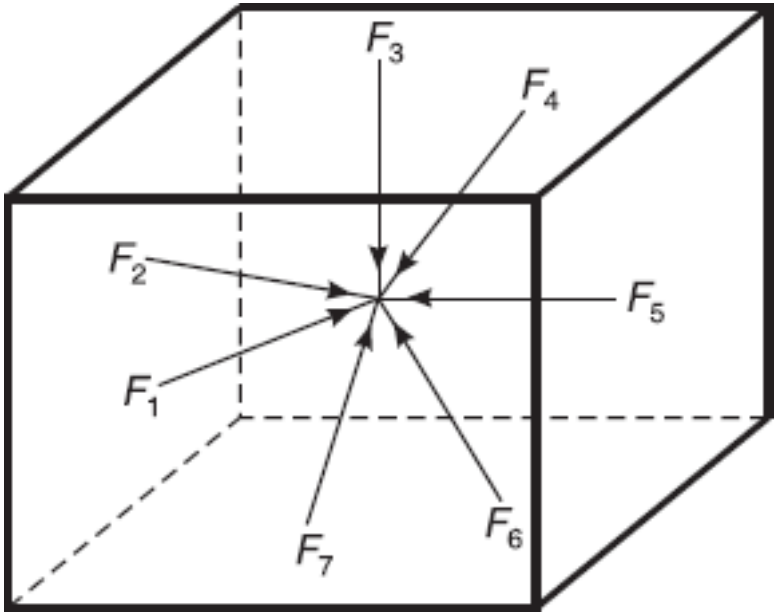


Figure.8 Non-coplanar concurrent force system

(ii) Non-coplanar non-concurrent force system

If two or more forces are acting on different planes but do not pass through the same point, they constitute a non-coplanar non-concurrent force system. As shown in Figure 9.

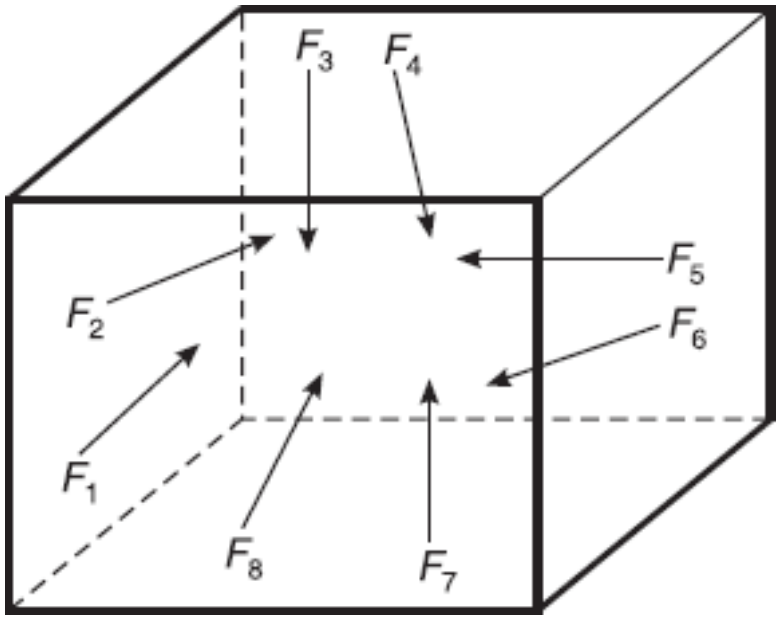


Figure.9 Non-coplanar non-concurrent force system

(iii) Non-coplanar parallel force system.

If two or more forces are acting in different planes and are parallel to one another, the system is said to be a non-coplanar parallel force system. As shown in Figure 10.

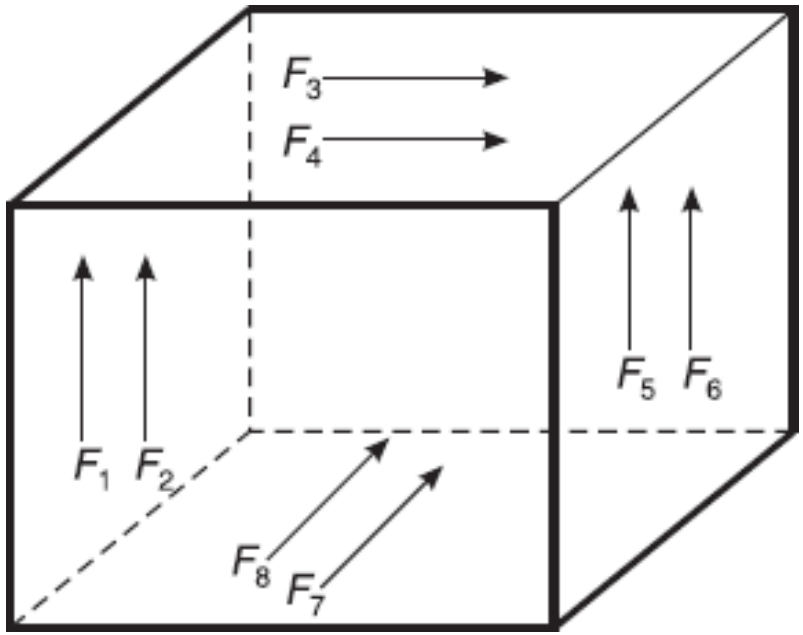


Figure.10 Non-coplanar parallel force system

Collinear force system

If the lines of action of two or more forces coincide with one another, it is called a collinear force system as shown in Figure.11.

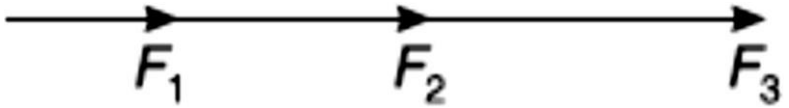


Figure.11 Collinear force system.

Non-collinear force system

If the lines of action of the forces do not coincide with oneanother, it is called a non-collinear force system as shown inFigure.12.

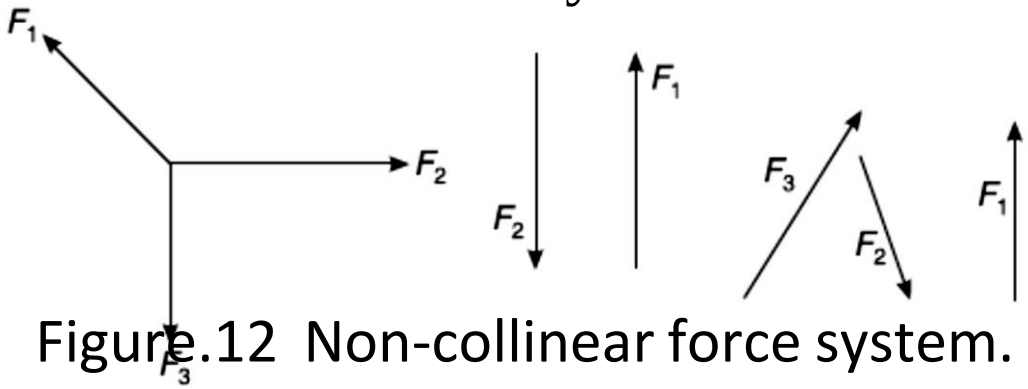


Figure.12 Non-collinear force system.

Principle of Transmissibility of Forces

This principle states that a force can be transmitted from one point to another point along the same line of action such that the effect produced by the force on a body remains unchanged.

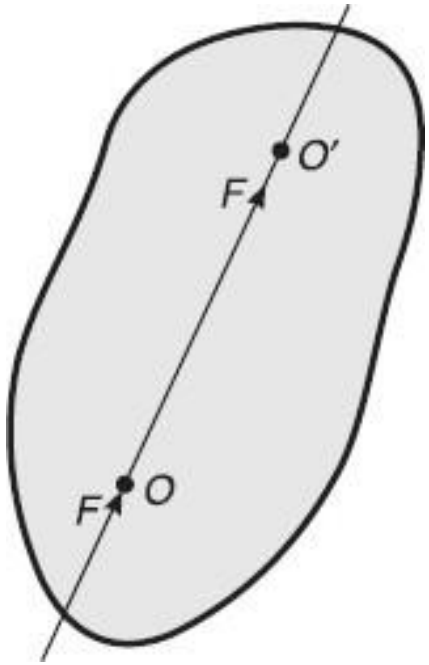


Figure.13 Transmissibility of force F from point O to O'.

Resolution of a Force

The process of splitting of a force into its two rectangular components (horizontal and vertical) is known as resolution of the force, as shown in Figure.14.

In this figure, F is the force which makes an angle θ with the horizontal axis, and has been resolved into two components, namely Fx and Fy, along the x-axis and y- axis respectively.

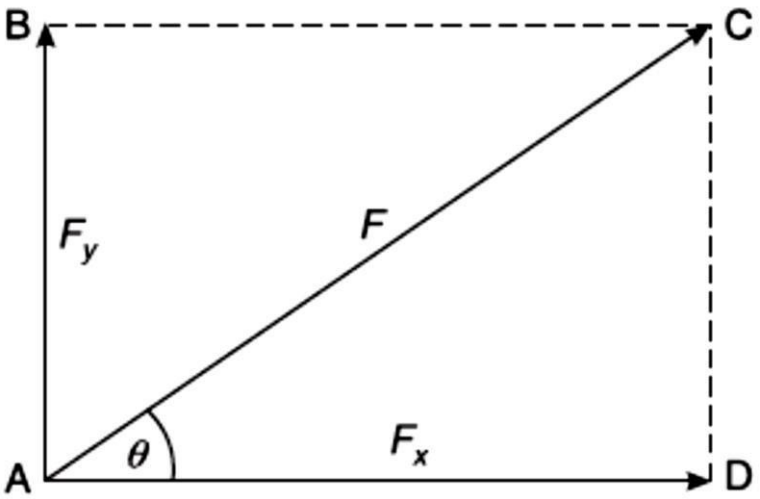
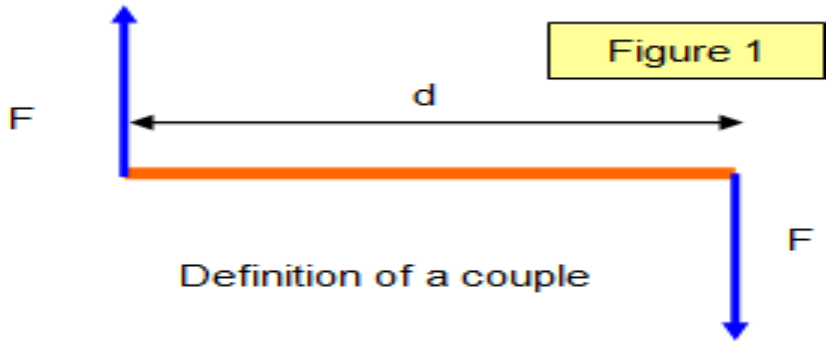


Figure.14 Resolution of a force.

Couple

A couple consists of two parallel forces that are equal in magnitude, opposite in sense and do not share a line of action. It does not produce any translation, only rotation. The resultant force of a couple is zero. but, the resultant of a couple is not zero; it is a pure moment.



Moment of a couple

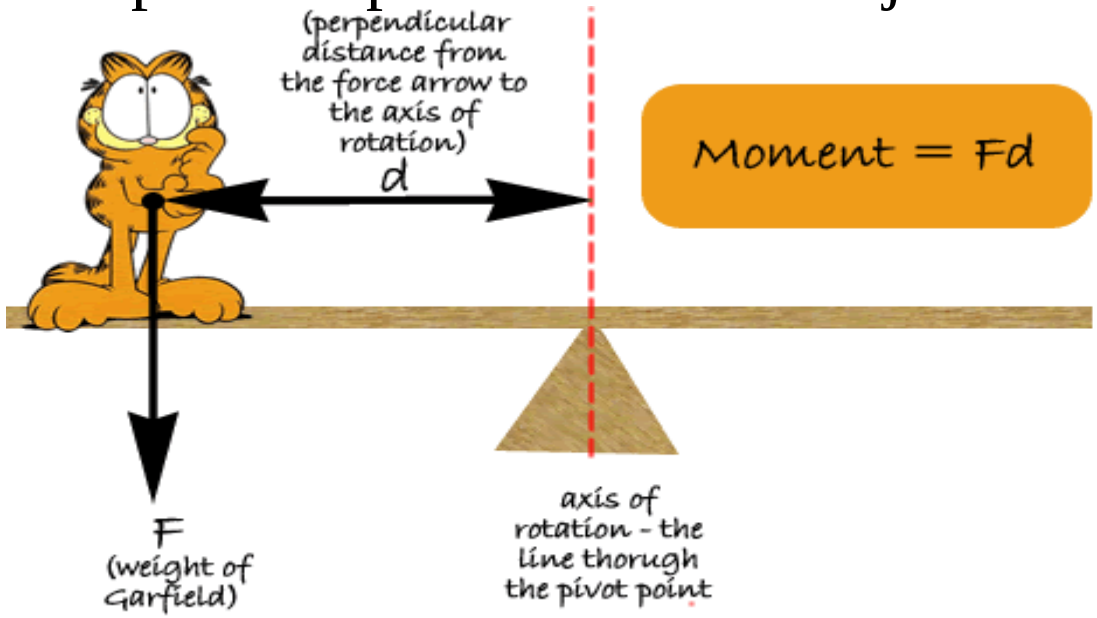
The tendency of a force is to rotate a body. It is measured by the moment of the force. The product of one of the two forces of a Couple and the perpendicular distance between their lines of action (called the arm of the Couple) is called the **Moment of Couple**.

Characteristics of couple

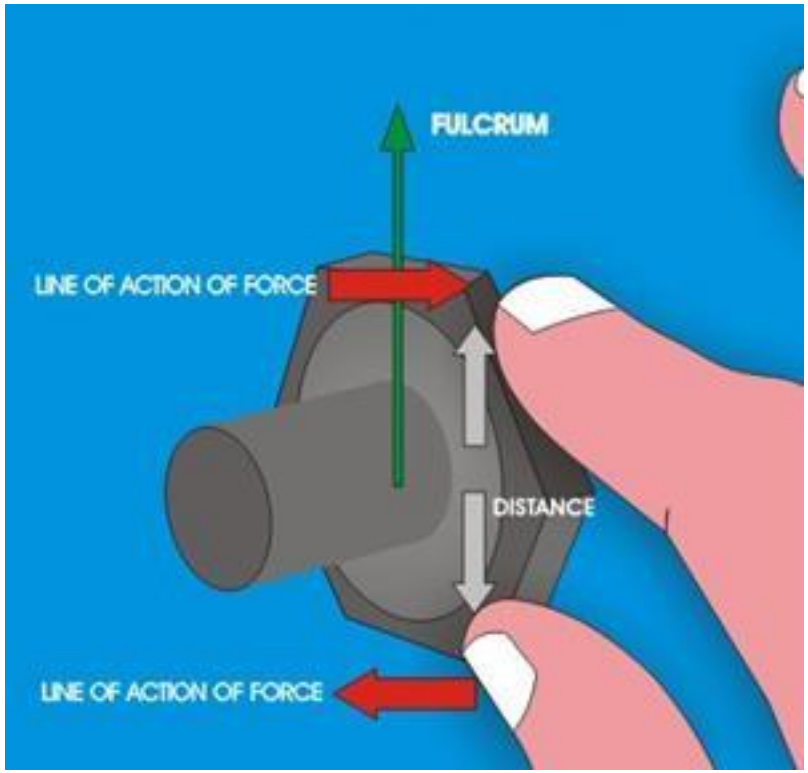
1. The algebraic sum of the forces consisting the couple is zero
2. The algebraic sum of the moment of the forces constituting the couple about any point is the same and equal to the moment of the couple itself.
3. A couple cannot be balanced by a single force but can be balanced only by a couple but of opposite sense.
4. Any number of coplanar couples can be reduced to a single couple whose magnitude will be equal to the algebraic sum of the moments of all the couples.

Moment of Force

1. The turning effect of a force (torque) is known as the moment.
2. It is the product of the force multiplied by the perpendicular distance from the line of action of the force to the pivot or point where the object will turn.

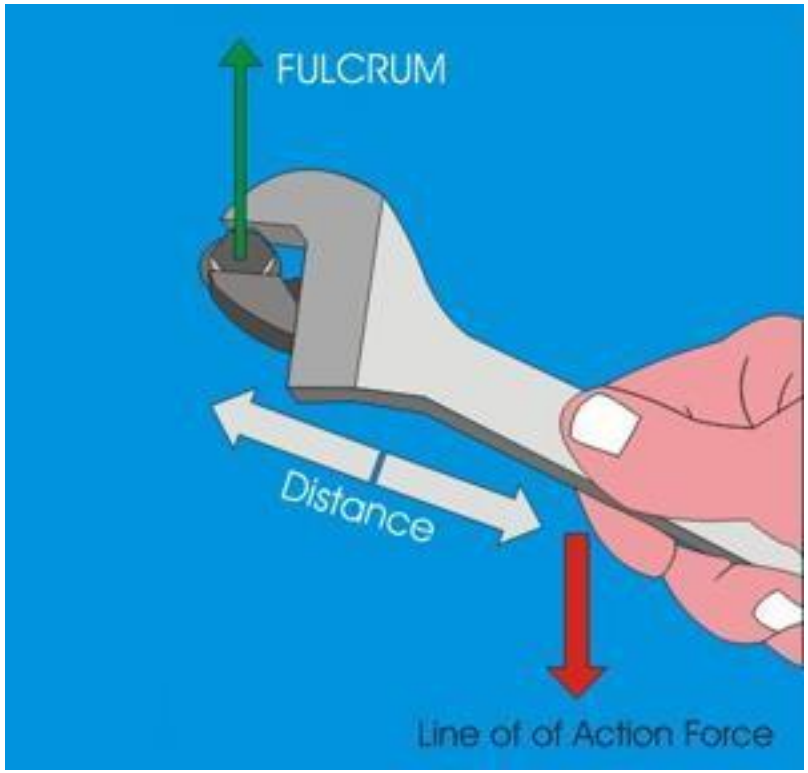


Moment of Force



SMALL MOMENT

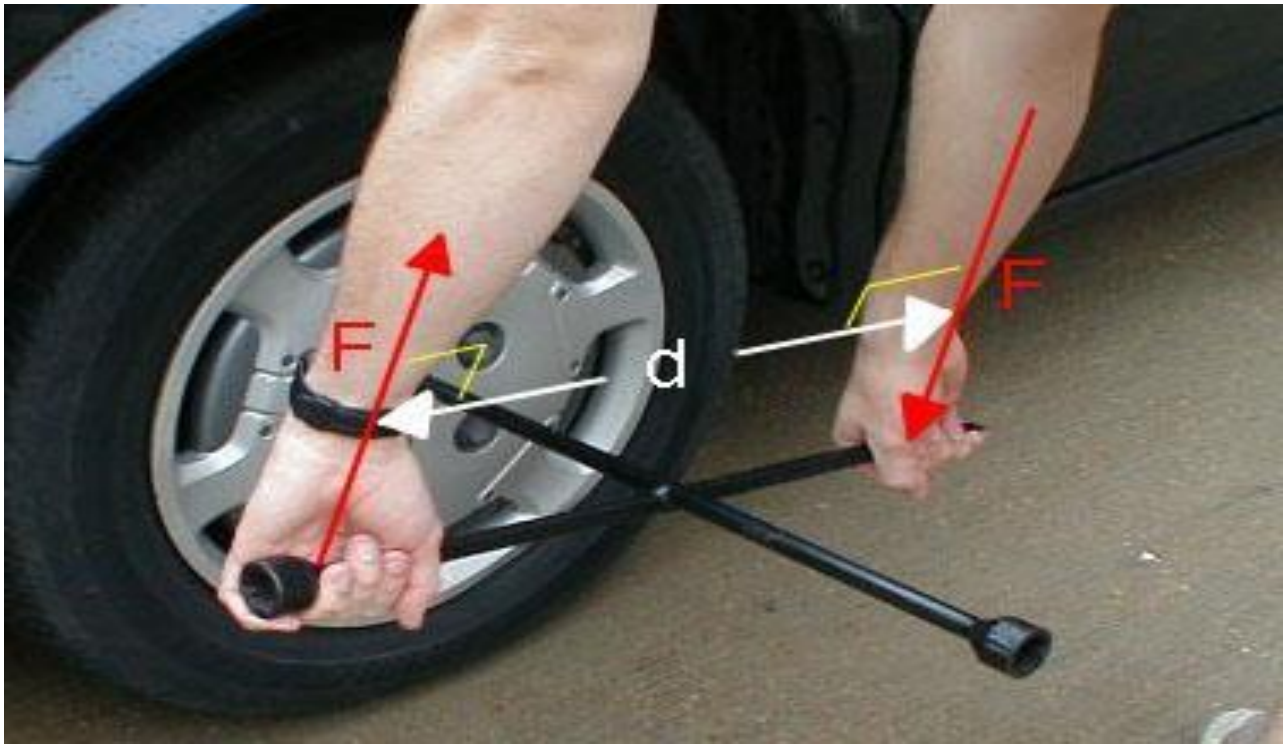
The distance from the fulcrum to the line of action of force is very small



LARGE MOMENT

The distance from the fulcrum to the line of action of force is large

Moment of Force

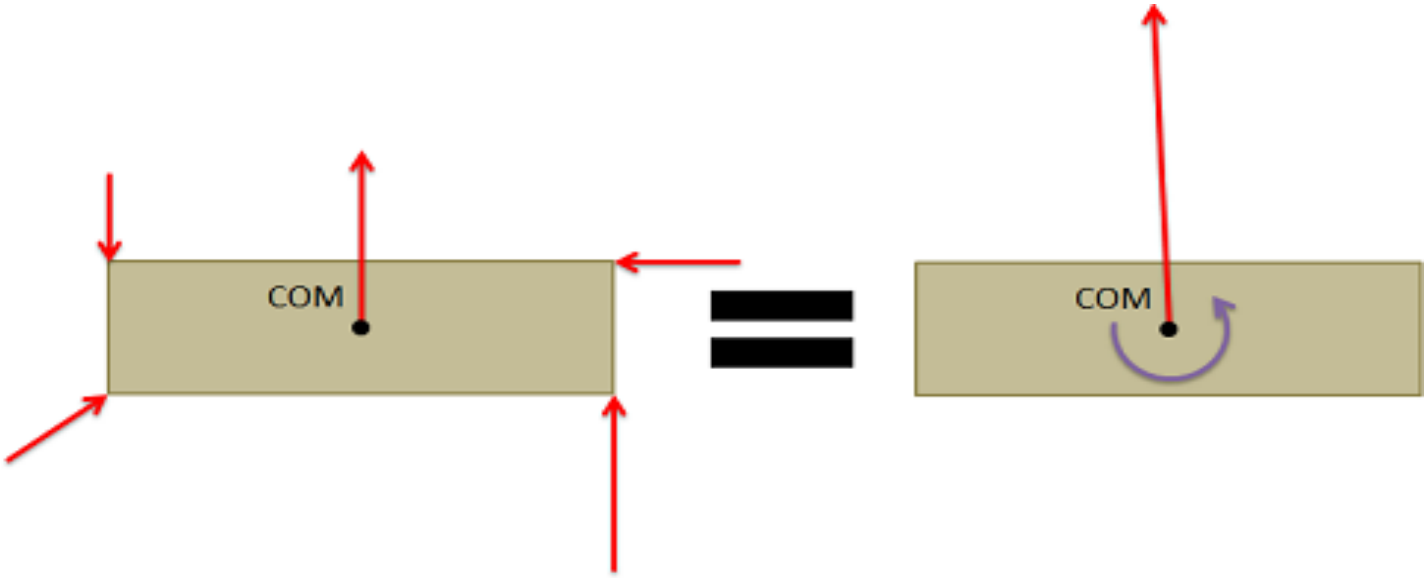


- Moments taken are about a point are indicate as being clockwise or counterclockwise
- For the sake of uniformity in calculation, assume clockwise to be +ve and counterclockwise to be -ve.

- Moment can expressed as Nm or kNm

Equivalent force couple system

Every set of forces and moments has an **equivalent force couple system**. This is a single force and pure moment (couple) acting at a single point that is **statically equivalent** to the original set of forces and moments



COUPLE

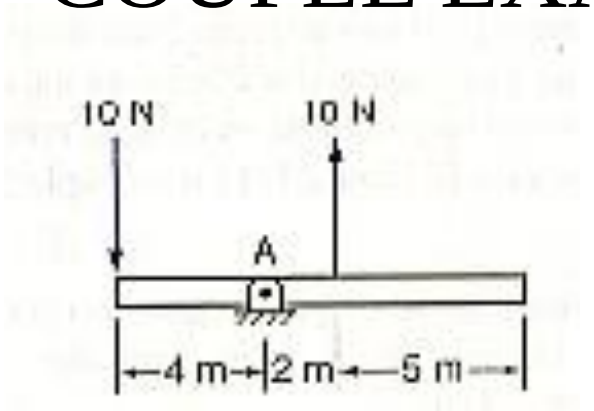
- These force could have been treated as a couple, which consists of two forces that are:
  1. Equal
  2. Acting in opposite direction
  3. Separated by some perpendicular distance d
- These three requirement of couple, from the example, we have;

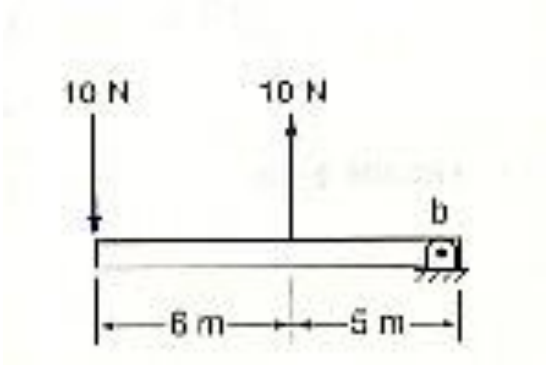
$$\text{Couple moment} = (F)\,(d)$$

$$= -5\,(20)$$

$$= -100 \text{ kNm}$$

COUPLE EXAMPLE





M_A=-(10N)(4m)-(10N)(2m)
=-40-20
=-60 N.m
=60N.m

M_b=-(10N)(11m)(10N)(5m)
= -110+50
= -60 N.m
= 60N.m

Resultant A force and couple system

- When a rigid body is subjected to a system of forces and couple moments
  - The external effects on the body by replacing the system by an equivalent single resultant force acting at a specified point **O** and a resultant couple moment

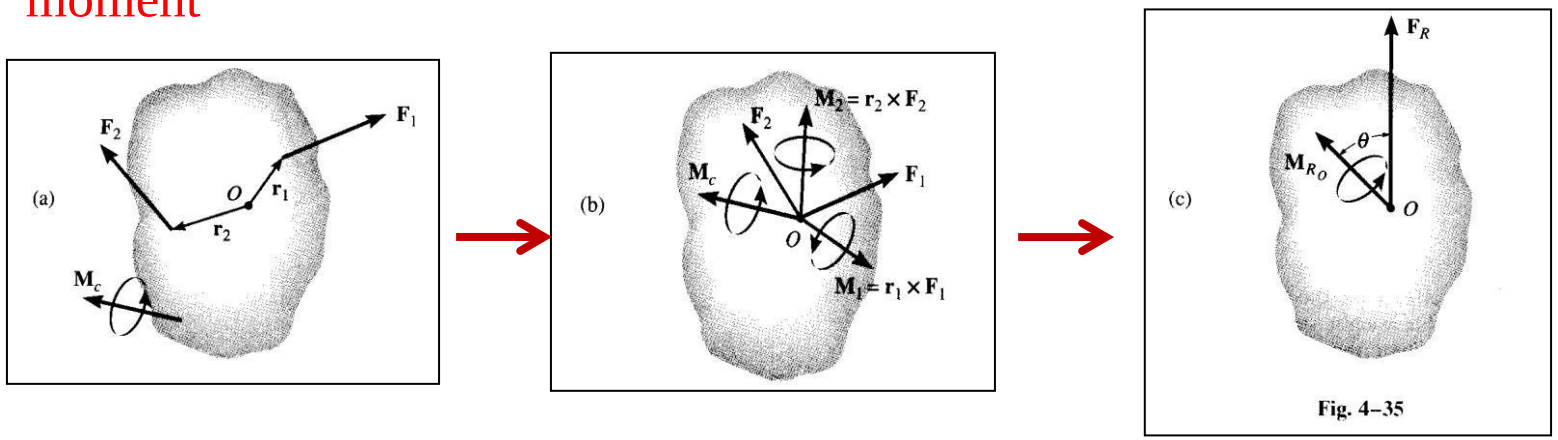
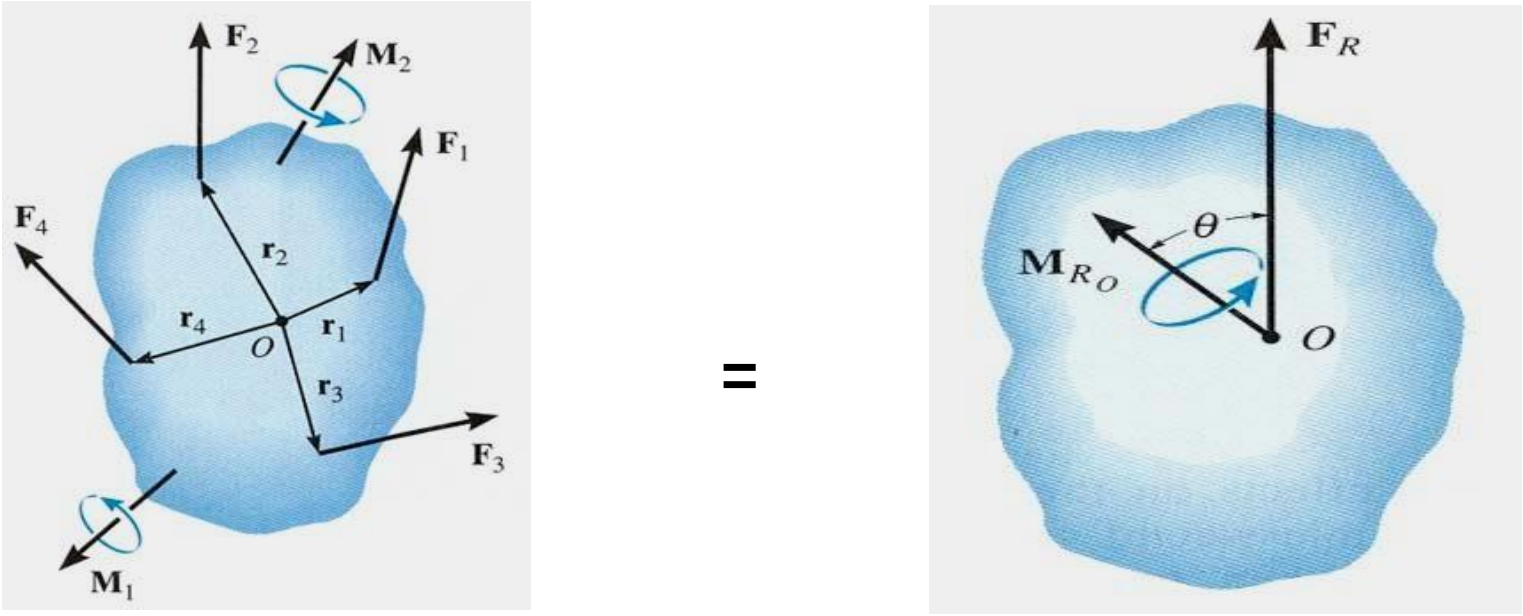


Fig. 4–35

  - Point **O** is not on the line of action of the forces, an equivalent effect is produced if the forces are moved to point **O** and the correspondingcouple moments $M_1=r_1xF_1$ and $M_2=r_2xF_2$ are applied to body

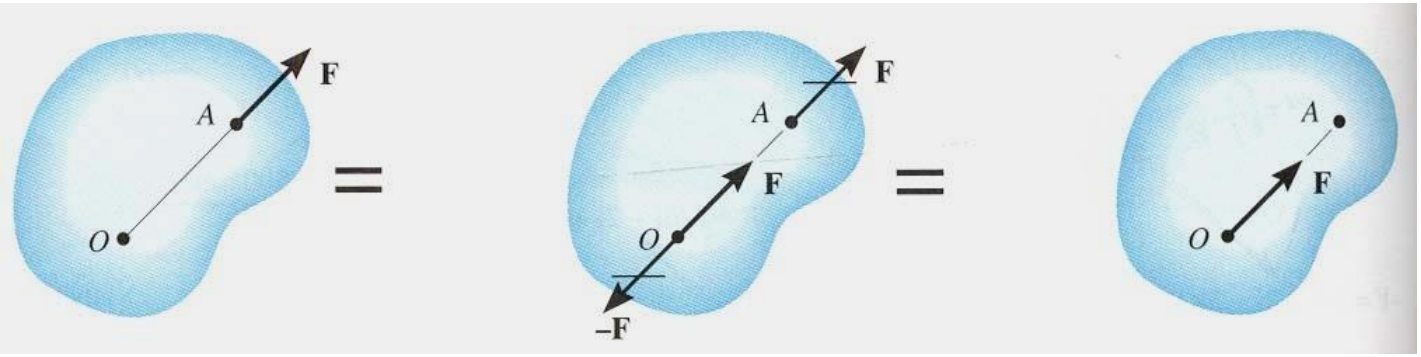
AN EQUIVALENT SYSTEM



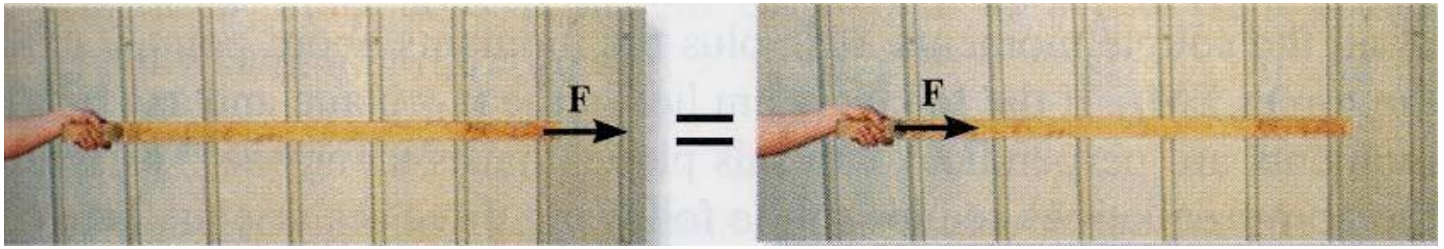
•When a number of forces and couple moments are acting on a body, it is easier to understand their overall effect on the body if they are combined into a single force and couple moment having the same external effect

•The two force and couple systems are called equivalent systems since they have the same external effect on the body.

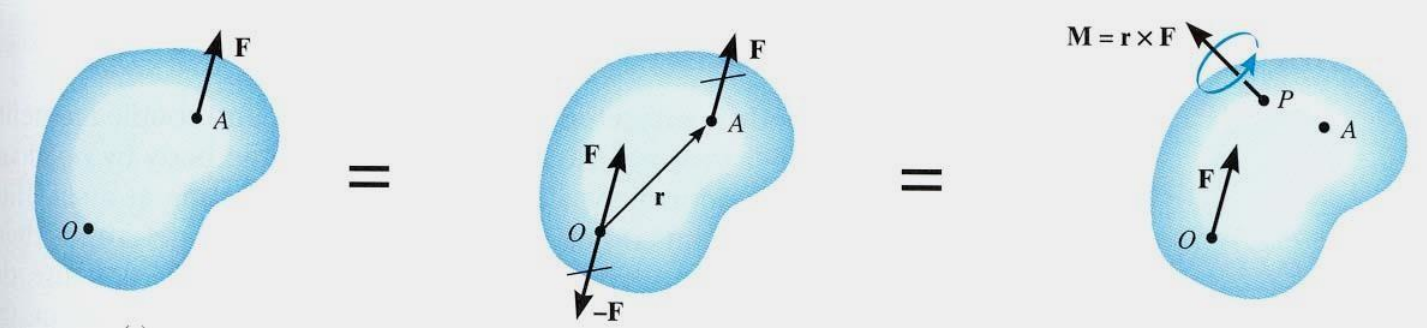
MOVING A FORCE ON ITS LINE OF ACTION



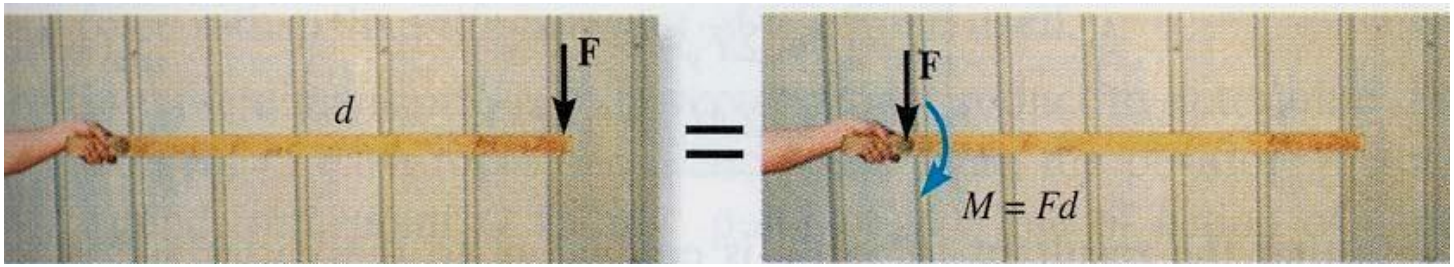
Moving a force from A to O, when both points are on the vectors' line of action, does not change the external effect.Hence, a force vector is called a sliding vector. (But the internal effect of the force on the body does depend on where the force is applied).



MOVING A FORCE OFF OF ITS LINE OF ACTION



Moving a force from point A to O (as shown above) requires creating an additional couple moment. Since this new couple moment is a "free" vector, it can be applied at any point P on the body.



Newton's law of motion

- **Newton's First Law of Motion**

Newton's 1st law states that a body at rest or uniform motion will continue to be at rest or uniform motion until and unless a net external force acts on it.

- **Newton's Second Law of Motion**

Newton's 2nd law states that the acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, andinversely proportional to the object's mass.

Newton's law of motion

Mathematically, we express the second law of motion as follows:

$fa \propto dP/dt$

$\Rightarrow fa \propto (mv - mu)/t$

$\Rightarrow fa \propto m(v - u)/t$

$\Rightarrow fa \propto ma$

$\Rightarrow f = kma$

In the equation, k is the constant of proportionality, and it is equal to 1 when the values are taken in the SI unit.

Hence, the final expression will be,

$$F = ma$$

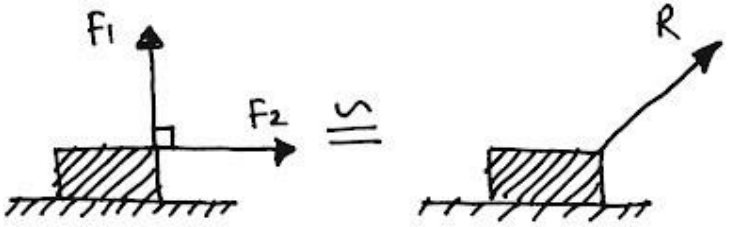
Newton’s law of motion

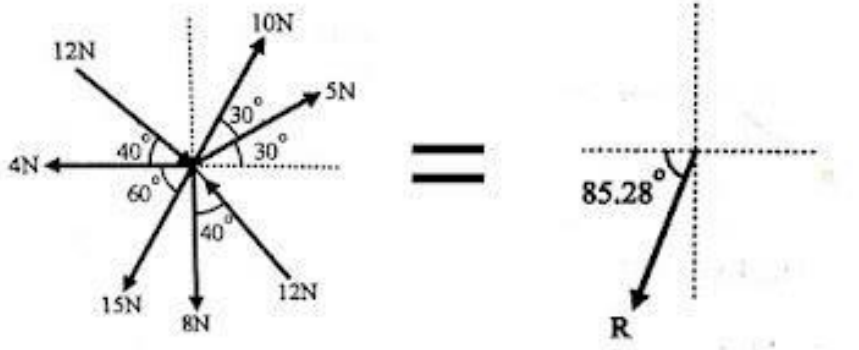
- **Newton’s Third Law of Motion**

Newton’s 3rd law states that there is an equal and opposite reaction for every action.

Composition of forces

It is the process of combining a number of forces into a single force such that net effect produced by single force is equal to the algebraic sum of the effects produced by the individual forces. The single force is called resultant which produces same effect on the body as that produced by the individual forces acting together





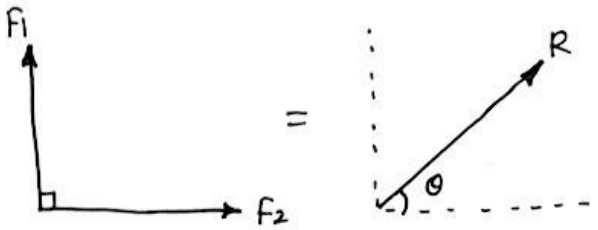
- **Method Of Composition (To find "R")**

A) Composition of perpendicular or orthogonal forces:-

When two or more coplanar concurrent or non-concurrent forces acting on a body then the resultant can determine by following procedure.

If F1 and F2 are the two forces which are perpendicular to each other as shown in fig,

Then resultant can be found out by following equation.



Magnitude of resultant

$$R = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$$

and Direction $\tan\theta = \dfrac{\Sigma F_y}{\Sigma F_x}$

Where,

ΣF_x = Algebraic sum of all x-components (or x component of resultant)

ΣF_y = Algebraic sum of all y-components (or y component of resultant)

θ = Angle of 'R' with x-axis.

B) Composition by parallelogram law of forces:-

Parallelogram law: If two forces are acting simultaneously on a particle and away from the particle, with the two adjacent sides of the parallelogram representing both the magnitude and direction of forces, the magnitude and direction of the resultant can be represented by the diagonal of the parallelogram starting from the common point of the two forces. See Figure 2.18.

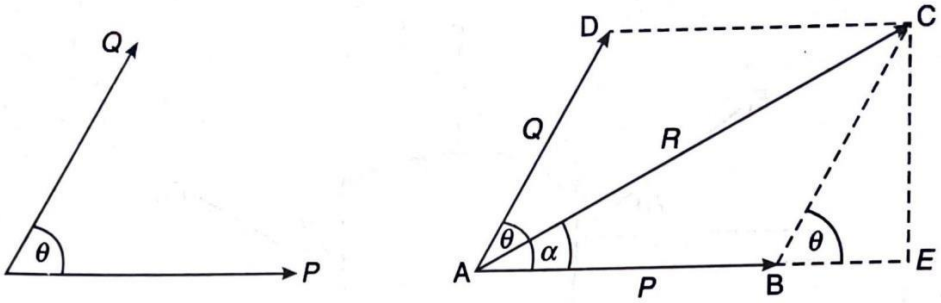


Figure 2.18 Parallelogram law of forces.

Let P and Q be the two forces, represented by the sides AB and AD of the parallelogram, the resultant can then be represented by AC as shown below:

To find the magnitude R of the resultant, consider the Δ CAE, where

$$AC^2 = AE^2 + CE^2$$
$$= (AB + BE)^2 + (CE)^2$$

B) Composition by parallelogram law of forces:-

Consider the Δ CBE, where

$$CE = Q \sin\theta$$

$$BE = Q \cos\theta$$

$$\therefore \quad AC^2 = AB^2 + 2AB \cdot BE + BE^2 + CE^2$$

or
$$R^2 = P^2 + 2 \cdot P \cdot Q \cos\theta + Q^2 \cos^2\theta + Q^2 \sin^2\theta$$

$$= P^2 + Q^2 + 2PQ \cos\theta$$

i.e.
$$R = \sqrt{P^2 + Q^2 + 2PQ \cos\theta}$$

To find the direction α of the resultant, consider the Δ CAE, where

$$\tan\alpha = \frac{CE}{AB + BE}$$

$$= \frac{Q \sin\theta}{P + Q \cos\theta}$$

$$\therefore \quad \alpha = \tan^{-1}\left(\frac{Q \sin\theta}{P + Q \cos\theta}\right)$$

Conditions

(i) Resultant R is max when two forces collinear and are in the same direction. $i.e.,\ \alpha = 0^{\circ} \quad \Rightarrow \quad R_{max} = P + Q$

(ii) Resultant R is min when two forces collinear but acting in the opposite direction. That is $\alpha = 180$ => Rmin = P- Q

(iii) If a = 90, that is when the forces act at right angle, then

R = P2 + Q2

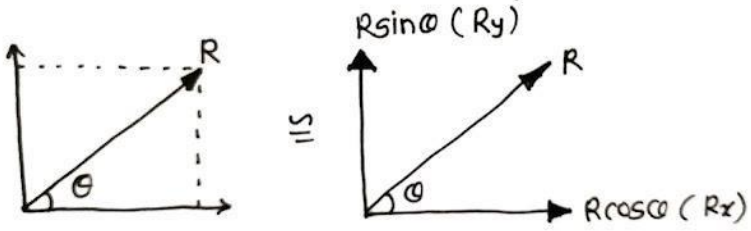
(iv) If the two forces are equal that is, when P = Q =>R = 2P.cos(θ/2)

Method Of Resolution:-

A) Orthogonal or perpendicular resolution:-

In this method the resultant force is split into two Perpendicular components. These two Perpendicular components will be acting along X-axis and Y-axis or any two Perpendicular axis.

As shown in fig R may be any force which is inclined at an angle θ with X-axis. So by using this method we can easily resolved this force into two Perpendicular or orthogonal components as shown in fig.

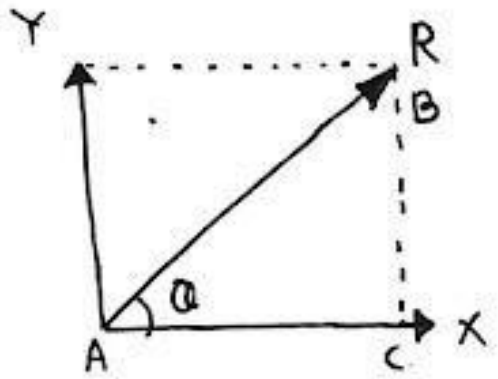


Rx= horizontal component of force R

Ry= vertical component of force R

Now from where these Rcosθ & Rsinθ c

Method Of Resolution:-



In fig. ΔABC is a right angled triangle.

$\therefore$ In ΔABC

$\sin\theta = \frac{BC}{AB}$

$\therefore BC = AB\sin\theta$

$\therefore \boxed{BC = R\sin\theta}$

$\because$ In ΔABC

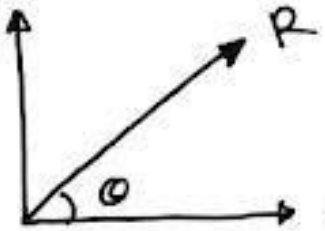
$\cos\theta = \frac{AC}{AB}$

$AC = AB\cos\theta$

$\boxed{AC = R\cos\theta}$

$R_y\ (R\sin\theta)$

$\therefore$



$R_x\ (R\cos\theta)$

$P_x = +P$

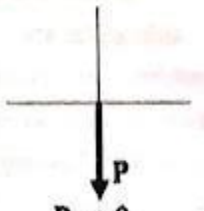
$P_y = 0$

$P_x = -P$

$P_y = 0$

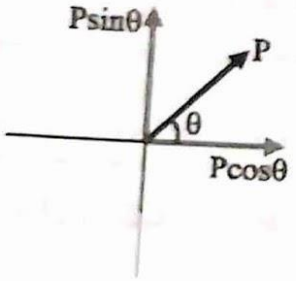
$P_x = 0$

$P_y = +P$



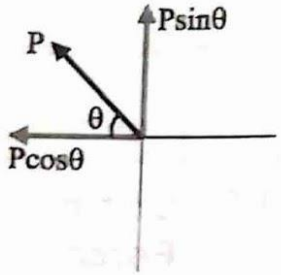
$P_x = 0$

$P_y = -P$



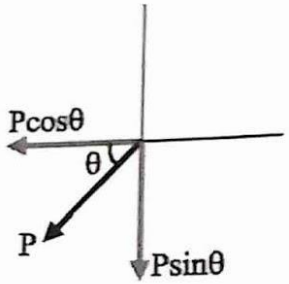
$P_x = +P\cos\theta$

$P_y = +P\sin\theta$



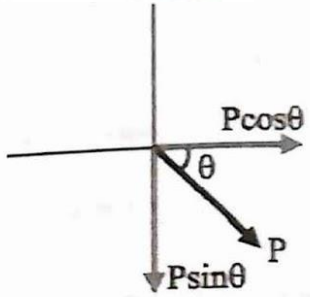
$P_x = -P\cos\theta$

$P_y = +P\sin\theta$



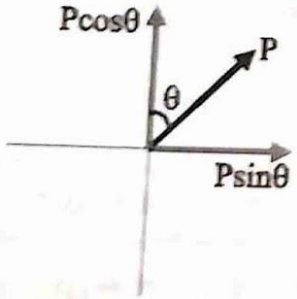
$P_x = -P\cos\theta$

$P_y = -P\sin\theta$



$P_x = P\cos\theta$

$P_y = -P\sin\theta$

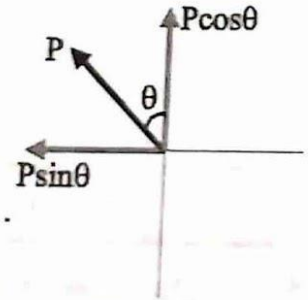


$P_x = P\cos(90^\circ - \theta)$

$= +P\sin\theta$

$P_y = P\sin(90^\circ - \theta)$

$= +P\cos\theta$



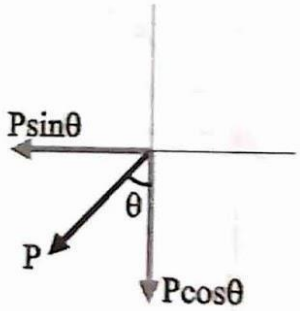
Similarly

$P_x = -P\cos(90^\circ - \theta)$

$= -P\sin\theta$

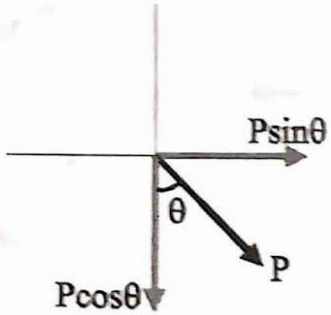
$P_y = +P\sin(90^\circ - \theta)$

$= +P\cos\theta$



$P_x = -P\sin\theta$

$P_y = -P\sin\theta$



$P_x = P\sin\theta$

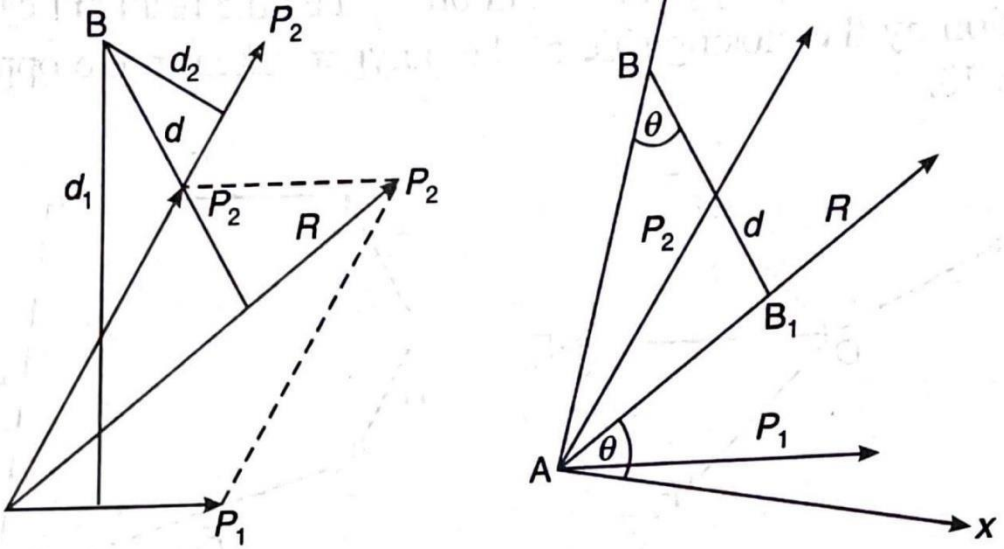
$P_y = -P\cos\theta$

Varignon's Theory of moments

This is also known as the principle of moments. The theorem states that "the algebraic sum of the moments of individual forces of a force system about a point is equal to the moment of their resultant about the same point. Let R be the resultant of forces P_1 and P_2 and B be the moment centre. Let d, d_1 and d_2 be the moment arms of forces R, P_1 and P_2, respectively, from the moment centre B (Figure 2.22).

We have to prove that

$$Rd = P_1 d_1 + P_2 d_2$$



Varignon's Theory of moments

Proof: Join AB and consider it as the y-axis and draw the x-axis at right angles to it at A. Let θ be the angle made by R with the x-axis and note that the same angle is formed with the y-axis by the perpendicular to R from B and note this point as B_1.

We know that,

$$Rd = R \times AB \cos\theta$$

$$= AB \times R \cos\theta$$

or
$$Rd = AB \times R_x \quad \text{(i)}$$

where R_x is the component of R in the x-direction. Similarly, if P_{1x} and P_{2x} are the components of P_1 and P_2 in the x-direction, respectively, then,

$$P_1 d_1 = AB \times P_{1x} \quad \text{(ii)}$$

and
$$P_2 d_2 = AB \times P_{2x} \quad \text{(iii)}$$

Adding equations (ii) and (iii), we get

$$P_1 d_1 + P_2 d_2 = AB(P_{1x} + P_{2x})$$

or
$$P_1 d_1 + P_2 d_2 = AB \times R_x \quad \text{(iv)}$$

Since the sum of x-components of the individual forces is equal to the x-component of the resultant R, from equations (i) and (iv), we can conclude that

$$Rd = P_1 d_1 + P_2 d_2$$

□

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BASICIS OF CIVIL ENGINEERING & MECHANICS

Course code:CV14/CV24

Credits:3:0:0

Topics Covered

Equilibrium of coplanar concurrent system of forces

Equilibrium of coplanar concurrent system of forces

EQUILIBRIUM

- When a stationary body is subjected to external forces and if the body remains in the state of rest under the action of forces, it is said to be in equilibrium.
- Equilibrium is also defined as the condition of a body, which is subjected to a force system whose resultant force is equal to zero. It means the effect of the given force system is zero and the particle or rigid body is said to be in equilibrium.

For example, a particle subjected to two forces will be in equilibrium when the two forces are equal in magnitude, opposite in direction and act along the same line of action as shown in Figure.

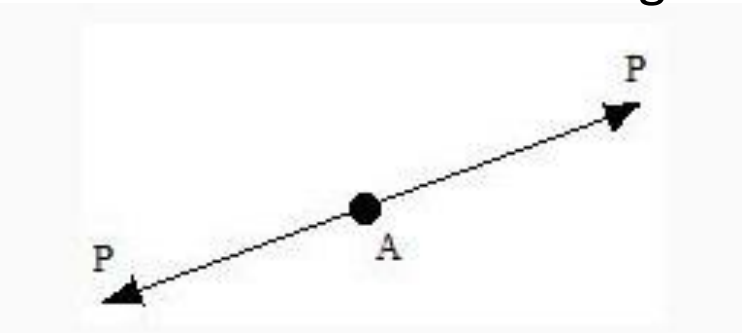


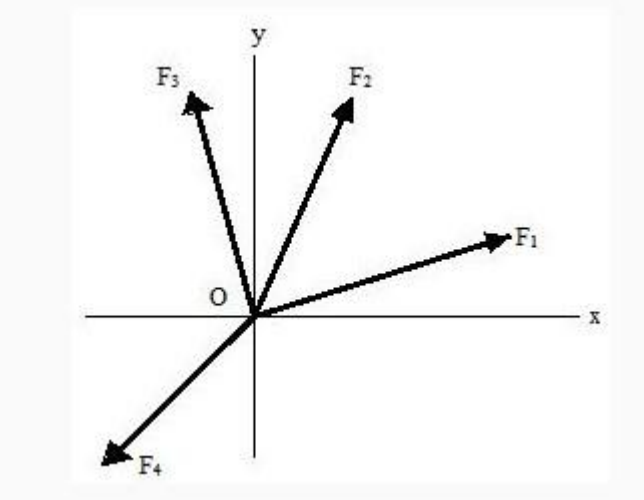
Fig. Equilibrium of forces

Conditions of equilibrium for coplanar concurrent force system

A coplanar concurrent force system will be in equilibrium if it satisfies the following two conditions:

1. Algebraic sum of all the horizontal components of the force system must be zero. i.e., $\sum F_x = 0$

2. Algebraic sum of all the vertical components of the force system must be zero. i.e., $\sum F_Y = 0$



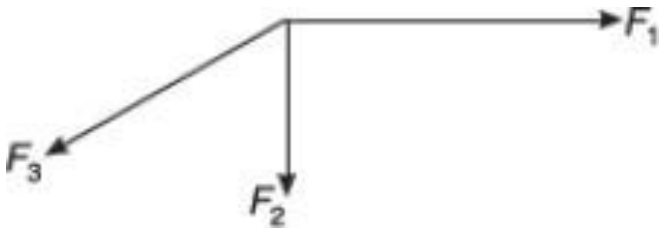


Figure. Coplanar Concurrent force system (2D Rigid Body Equilibrium)

Conditions of equilibrium for coplanar nonconcurrent force system

A coplanar non concurrent force system will be in equilibrium if it satisfies the following three conditions:

1. Algebraic sum of all the horizontal components of the force system must be zero. i.e., $\sum F_X = 0$

2. Algebraic sum of all the vertical components of the force system must be zero. i.e., $\sum F_Y = 0$

3. Algebraic sum of moments of all the forces about any point system must be zero. i.e., $\sum M = 0$

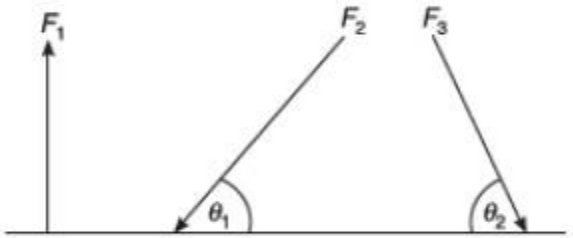
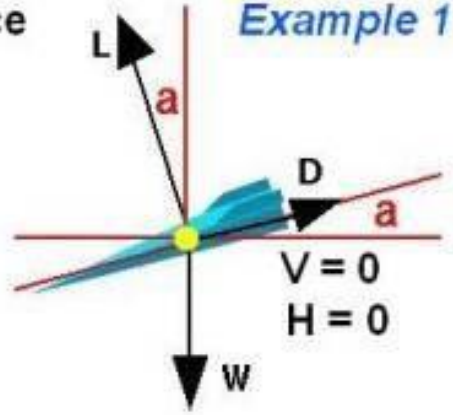


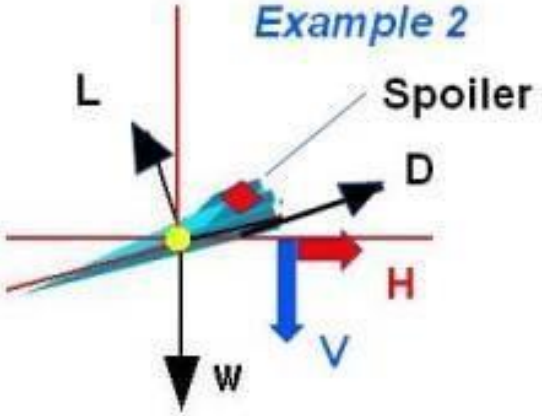
Figure. Coplanar non-concurrent force system

H = Horizontal Force
V = Vertical Force
W = Weight
D = Drag
L = Lift
a = glide angle

Example 1



Example 2



Equilibrium

Vertical: $W - L\cos(a) - D\sin(a) = V = 0$

Horizontal: $D\cos(a) - L\sin(a) = H = 0$

No net external force
Aircraft descends at constant velocity

Non-equilibrium

$W - L\cos(a) - D\sin(a) = V$

$D\cos(a) - L\sin(a) = H$

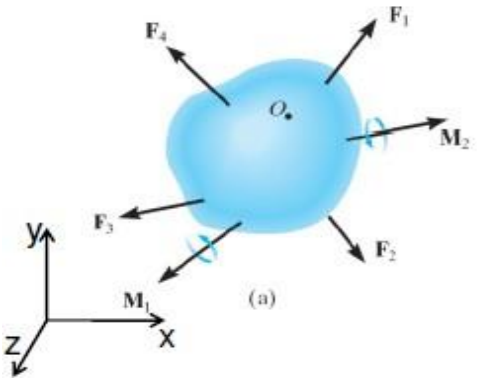
Net external forces
Aircraft accelerates vertically and horizontally

EQULIBRIUM OF A BODY IN SPACE

Rigid Body Equilibrium

A rigid body will remain in equilibrium provided

- sum of all the external forces acting on the body is equal to zero, and
- Sum of the moments of the external forces about a point is equal to zero



$$\Sigma F_x = 0$$
$$\Sigma F_y = 0$$
$$\Sigma F_z = 0$$

$$\Sigma M_x = 0$$
$$\Sigma M_y = 0$$
$$\Sigma M_z = 0$$

- A body is said to be in equilibrium if there is no translation and no rotation of the body under the application of external forces.

Equilibrant

Equilibrant is defined as a single force required to keep the body in equilibrium. For a concurrent force system, equilibrant is a force which has same magnitude as the resultant force but opposite in direction.

Free-body diagram (FBD)

A free body diagram represents only the forces acting in the system without representing the physical appearance of body.

Figure (a) shows a spherical ball of mass *m, placed on a horizontal plane and tied to the plane*

Figure (b) shows the free-body diagram of the Figure (a) where only the forces are represented without physical appearance of the body.

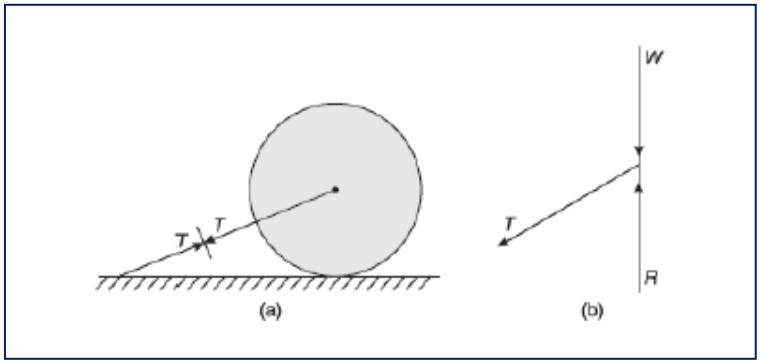


Figure. Spherical ball (on a horizontal plane) with free-body diagram.

The various forces are:

(i) Self weight, *W, always acting vertically downwards.*

(ii) Normal reaction, R, always acting perpendicular to the plane under consideration.

(iii) Tension *T in the string.*

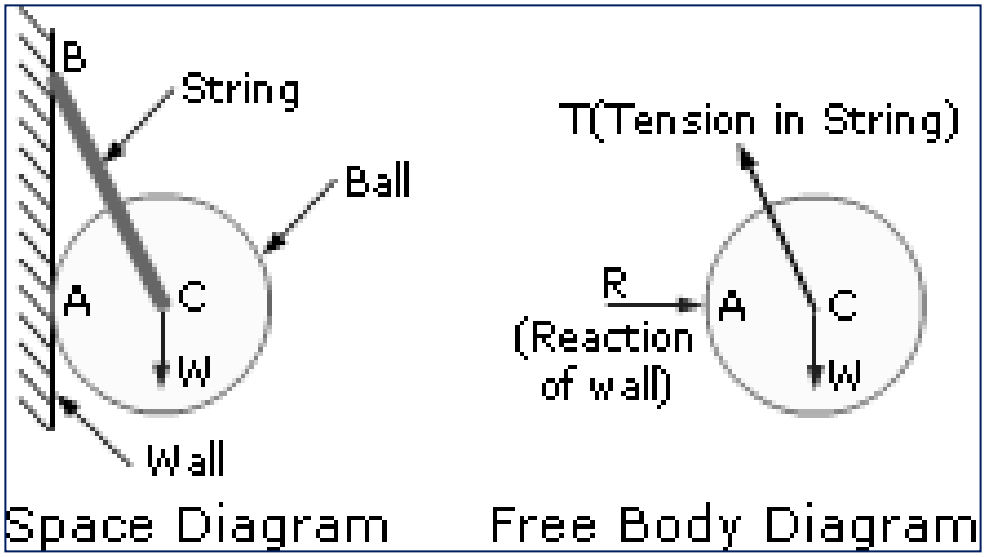


Figure. Spherical ball (resting against a wall)

In Figure above, a spherical ball supported by a string and resting against a wall, is shown together with its free-body diagram.

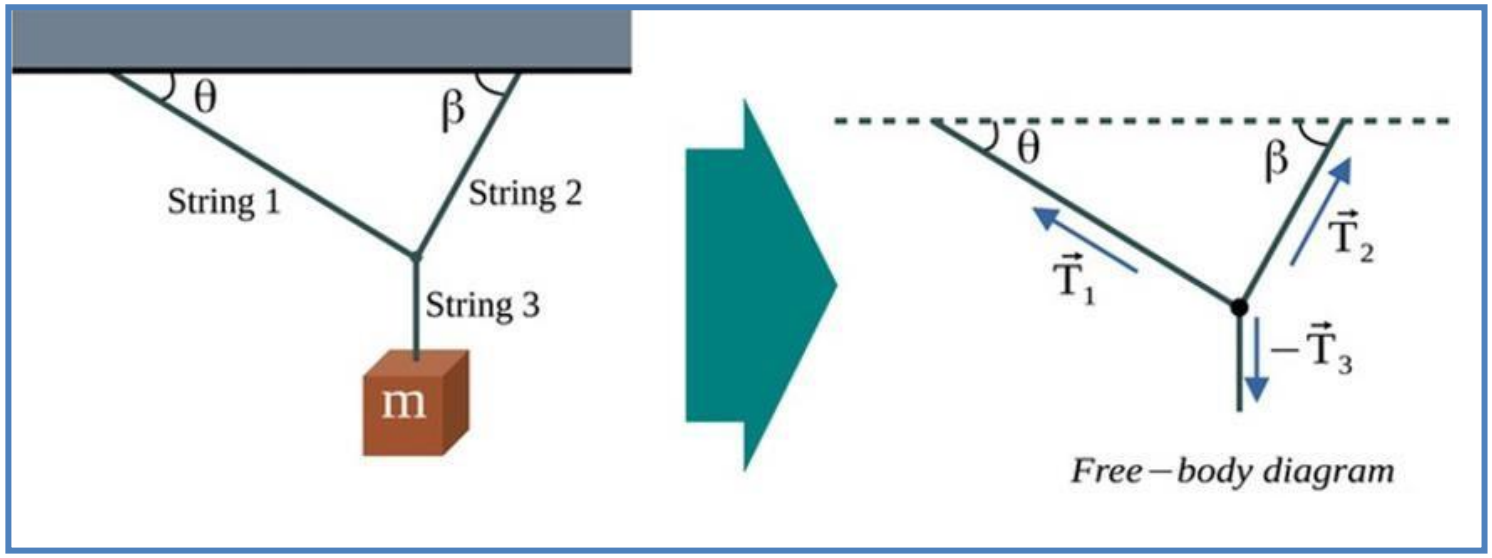


Fig. Free Body Diagram of a structure connected with Two strings

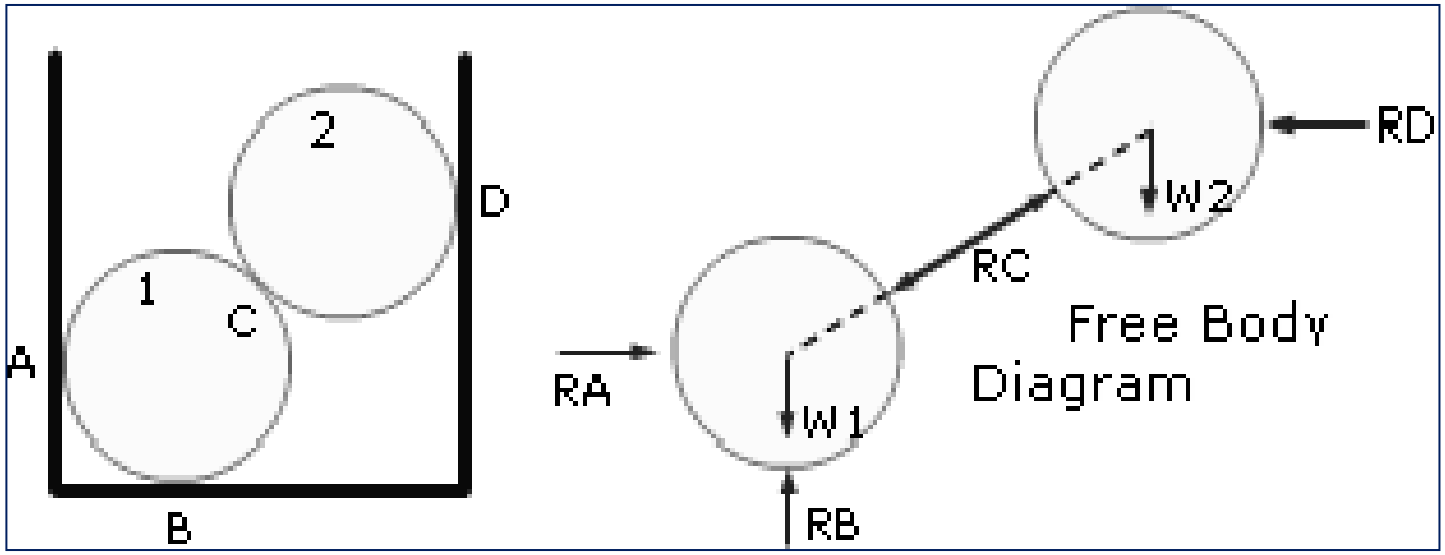
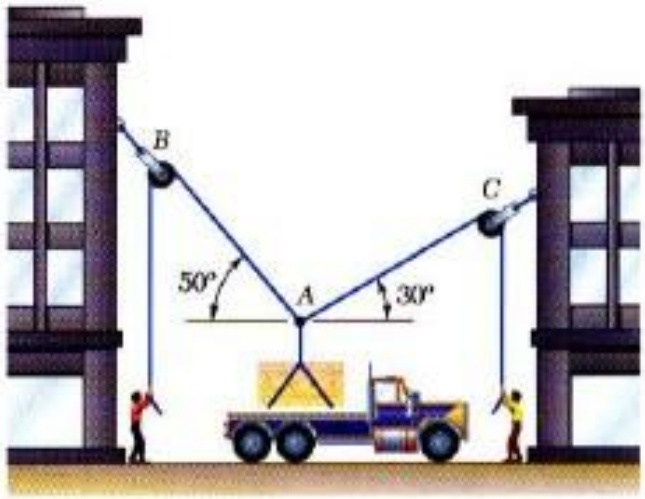
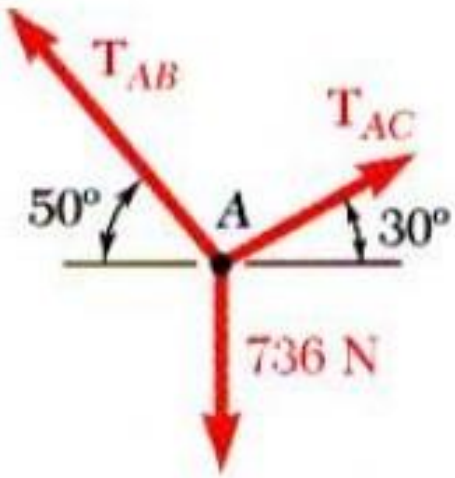


Fig. Free Body Diagram of connected bodies

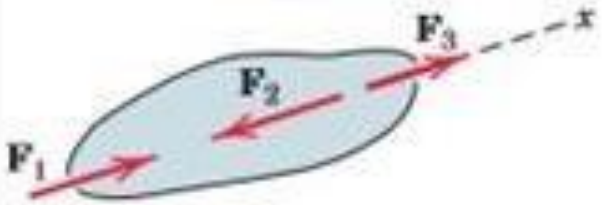
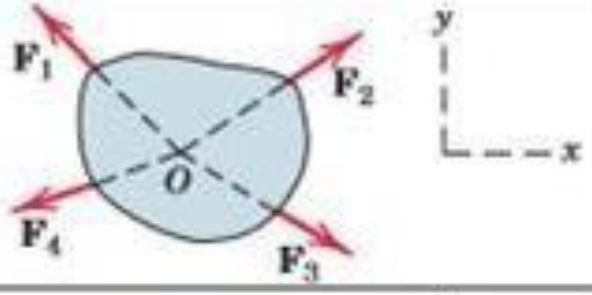
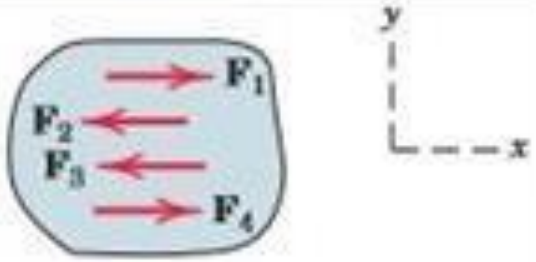
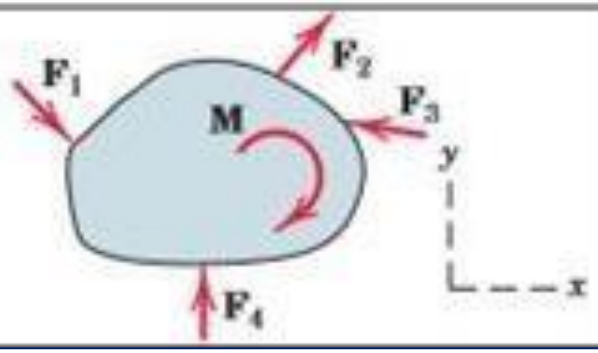


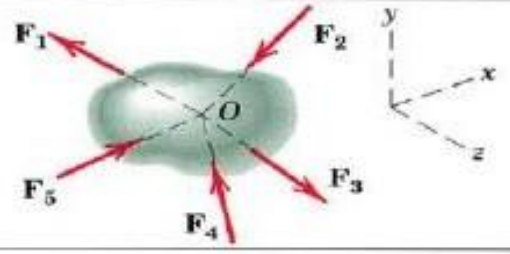
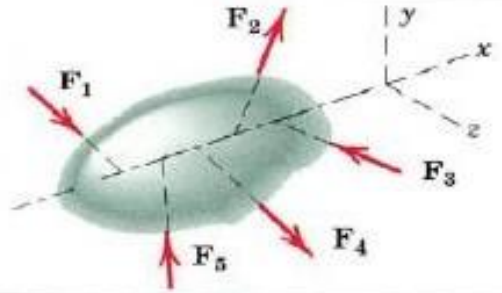
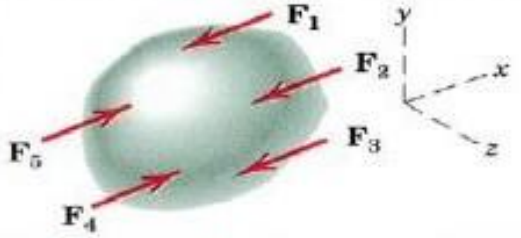
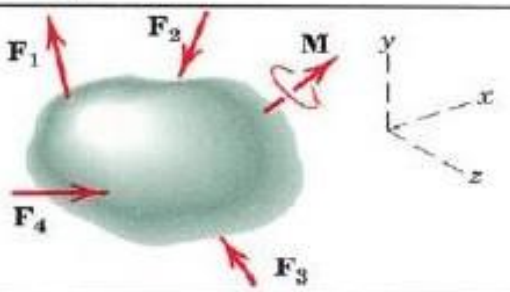
Space Diagram: A sketch showing the physical conditions of the problem.



Free-Body Diagram: A sketch showing only the forces on the selected particle.

CATEGORIES OF EQUILIBRIUM IN TWO DIMENSIONS

Force System	Free-Body Diagram	Independent Equations
1. Collinear		$\Sigma F_x = 0$
2. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$
3. Parallel		$\Sigma F_x = 0$ $\Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\Sigma M_z = 0$ $\Sigma F_y = 0$

CATEGORIES OF EQUILIBRIUM IN THREE DIMENSIONS			
Force System	Free-Body Diagram	Independent Equations	
1. Concurrent at a point		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$	
2. Concurrent with a line		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$	$\Sigma M_y = 0$ $\Sigma M_z = 0$
3. Parallel		$\Sigma F_x = 0$	$\Sigma M_y = 0$ $\Sigma M_z = 0$
4. General		$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma F_z = 0$	$\Sigma M_x = 0$ $\Sigma M_y = 0$ $\Sigma M_z = 0$

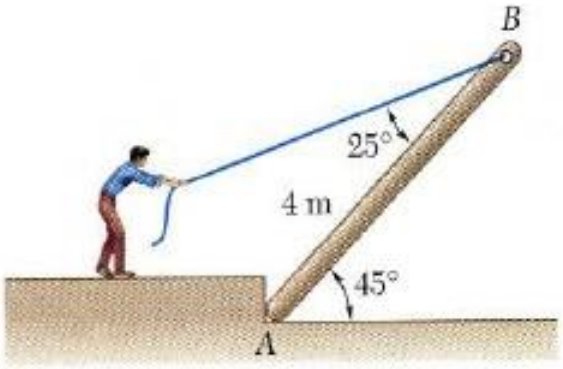
PROBLEMS ON EQUILIBRIUM OF COPLANAR CONCURRENT FORCE SYSTEM

1. First, draw Free Body Diagram of a point in the system/an object in the system/complete system of objects showing various forces acting on it.
2. In the coplanar concurrent force system, use two conditions of equilibrium, namely

$$\sum F_X = 0 \quad \text{and} \quad \sum F_Y = 0$$

3. Analyze the given problem by applying the above conditions of equilibrium.

Rigid Body Equilibrium: Example



A man raises a 10 kg joist, of length 4 m, by pulling on a rope.

Find the tension in the rope and the reaction at A.

Solution:

- Create a free-body diagram of the joist. Note that the joist is a 3 force body acted upon by the rope, its weight, and the reaction at A.
- The three forces must be concurrent for static equilibrium. Therefore, the reaction ***R*** must pass through the intersection of the lines of action of the weight and rope forces. Determine the direction of the reaction force ***R***.
- Utilize a force triangle to determine the magnitude of the reaction force ***R***.

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BASICIS OF CIVIL ENGINEERING & MECHANICS

Course code:CV14/CV24

Credits:3:0:0

Topics Covered

Equilibrium of Non Concurrent Force System

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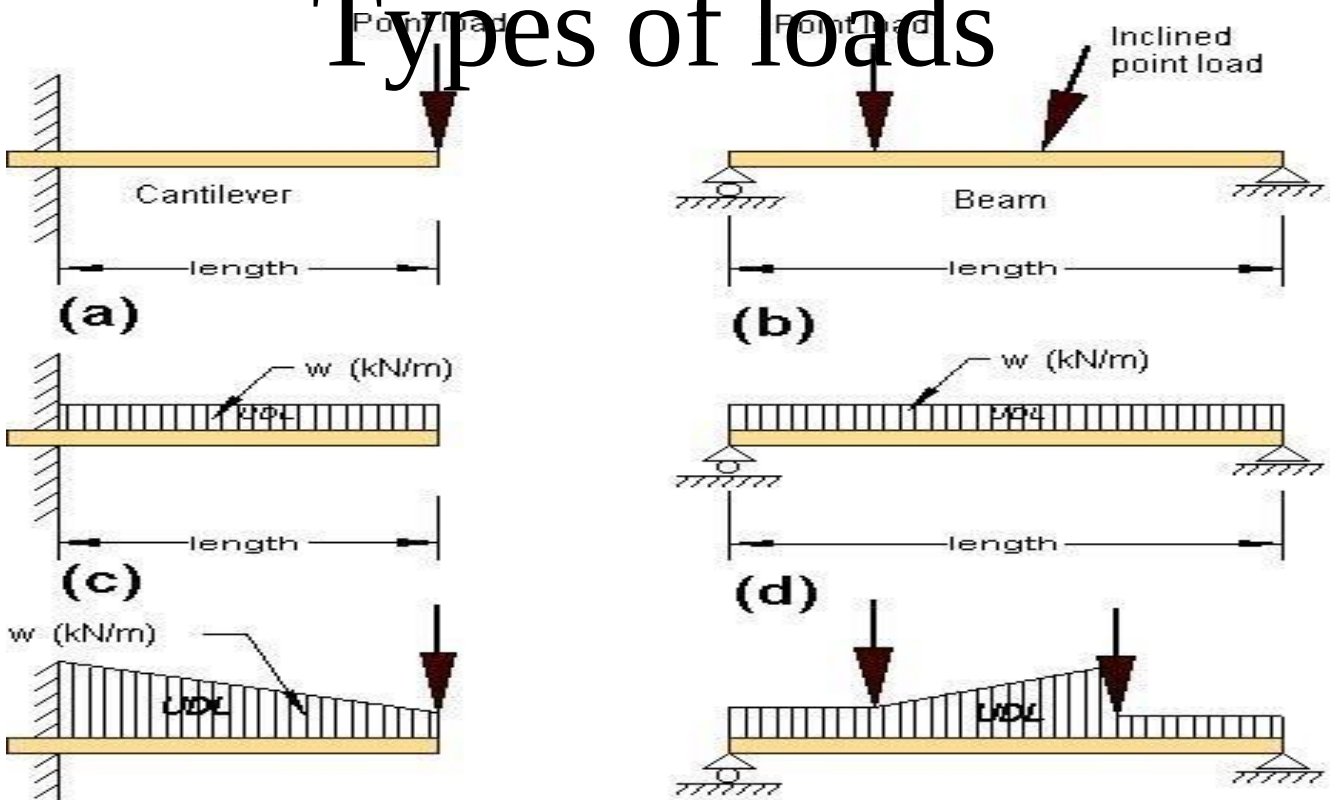
CIVIL ENGINEERING

Course: Basics of Civil Engineering &

Mechanics

Credits: 3:0:0

Types of loads



What is a structural support ???

Any thing which **take up** the **loads** coming from the **super structure** and **transfer** to **substructure**

- Structural **systems transfer** their **loading** through a **series of elements** to the **ground**.

- Each **connection is designed** so that it can **transfer or support** a specific type of **load or loading condition**.

- In order to **analyze a structure** it is **necessary to be clear** about the **forces that can be resisted and transferred** at each level of support throughout the structure.

The **actual behavior** of a **support or connection** can be **quite complicated if all conditions** were **considered** and the **design** of each support would be a **terribly lengthy process.**

For ex:

1. hinge support is considered as 100% friction free but it is not true.
2. There will also be vertical deformations in the elastomeric bearings which is ignored while designing.
3. While designing its no where considered temperature effects on the structural supports.

Structural steel systems → welded or bolted connections

Precast RCC or PSC systems → mechanically connected

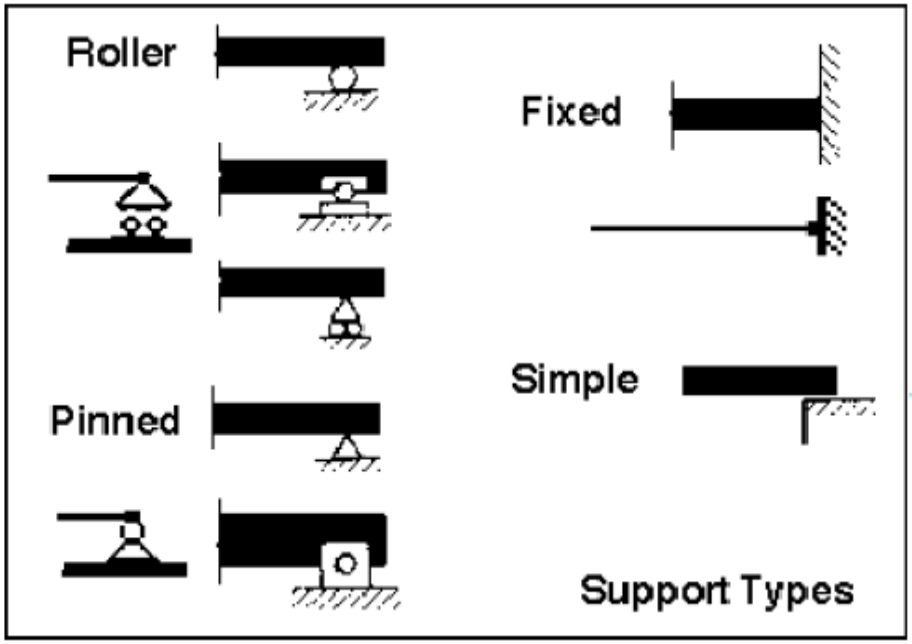
Cast-in-situ → monolithic connections

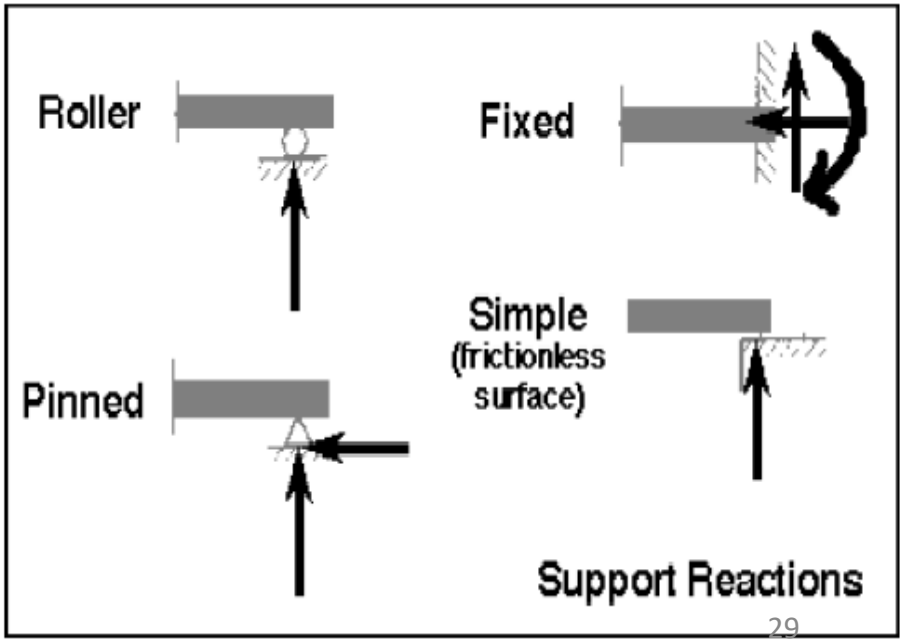
Timber systems → nails, bolts, glue &engineered connectors.

No matter the material the connection must be designed to have a specific rigidity.

There are generally four type of supports

- Roller support
- Hinge or pin support
- Fixed support
- Simple support






COBRA

- **Roller supports** are **free to rotate and translate** along the surface upon which the roller rests. The **surface** can be **horizontal vertical or sloped** at any angle.

- The **resulting reaction force** is always a **single force** that is **perpendicular** to the

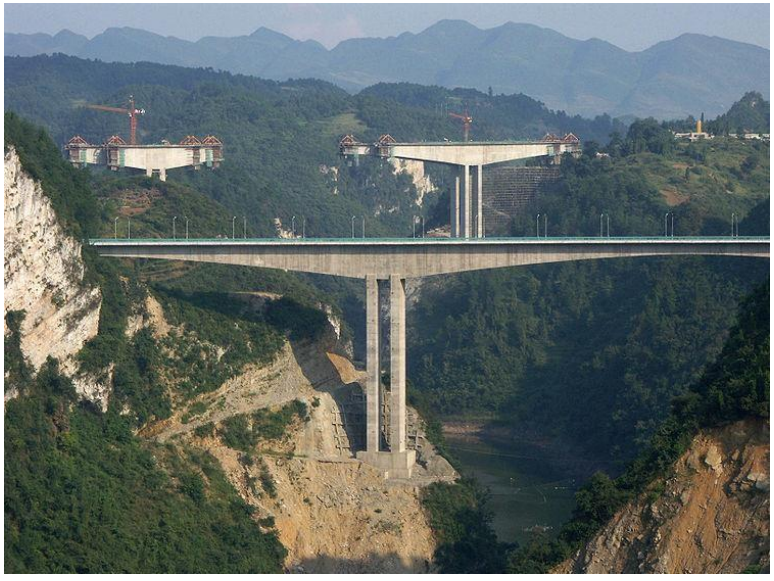
- Roller supports are **commonly located at one end of long bridges** . This **allows** the bridge structure to **expand and contract** with **temperature changes**.

- Roller supports can also **take the form of rubber bearings ,rockers** which are designed to **allow a limited amount of lateral movement.**

- A **pinned support** can **resist** both **vertical** and **horizontal forces** but **not a moment.**
- They will **allow** the **structural member** to **rotate** but **not to translate** in any direction.
- **Many connections** are **assumed to be pinned connections** even though **they might resist a small amount of moment in reality.**
- It is also true that a **pinned connection** could **allow rotation** in **only one direction** providing **resistance to rotation in any other direction**.

Ex :Pen stand is the example for the pin support which can allow rotation in all directions and also about its own axis.

Some of the fixed support



- **Fixed supports** can **resist vertical** and **horizontal forces** as **well as a moment. Since they restrain both rotation and translation** they are also **known as rigid supports.**

- **This means that a structure only needs one fixed support in order to be stable.** All three equations of equilibrium can be satisfied.

Ex: A **flagpole** set into a **concrete base** is a good example of this kind of support.

- **Fixed connections demand greater attention during construction and are often the source of building failures.**

- **Fixed connections** are very **common** both in **RCC and steel structures**.

- **Steel structures welded together** can be **considered** as **fixed connections**.

- A **cast-in-place concrete structure** is automatically **monolithic** and it becomes a series of **rigid connections** with the proper placement of the reinforcing steel.

Some of the simple support

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- Simple supports are **idealized** by some **to be frictionless surface supports**.

- This is correct in as much as **the resulting reaction** is always a **single force** that is **perpendicular** to and **away from the surface.**

- However are also **similar to roller supports in this**. They are **dissimilar in** that a simple support **cannot resist lateral loads** of any magnitude.

- A simple support **can be found as a** type of **support for long bridges** or roof span. **Simple supports** are **often found in** zones of **frequent seismic** activity.

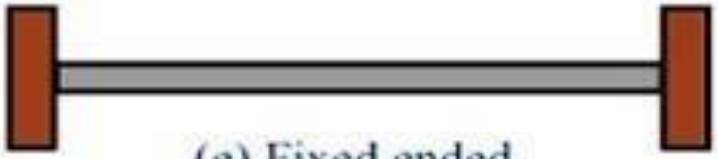
Types of Beams

(a) Cantilever

(b) Simply supported

(c) Overhanging

(d) continuous



(e) Fixed ended

(f) Propped cantilever beam.

Determinate beams

In beams, if the reaction forces can be calculated using equilibrium equations alone, they are statically determinate.

Ex: **simply supported beams, cantilever beams, singleand double overhanging beams,**

In determinate beams

In beams, if the reaction forces cannot be calculatedusing equilibrium equations alone, they are indeterminate.

Ex: **fixed beams, continuous beams**

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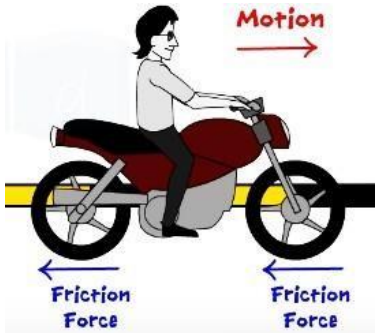
BASICIS OF CIVIL ENGINEERING & MECHANICS

Course code:CV14/CV24

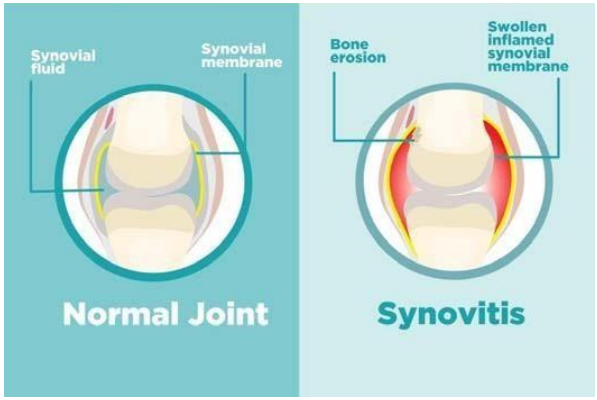
Credits:3:0:0

Topic Covered

Friction



HERO Or VILLAIN

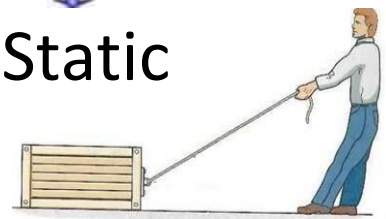


Types of Friction

State of rest/motion

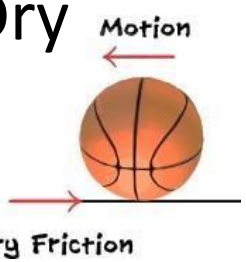
Contact surface

Static



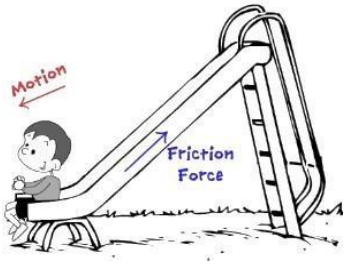
Dynamic

Dry

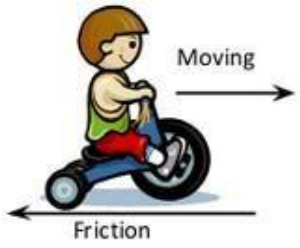


Fluid

Sliding

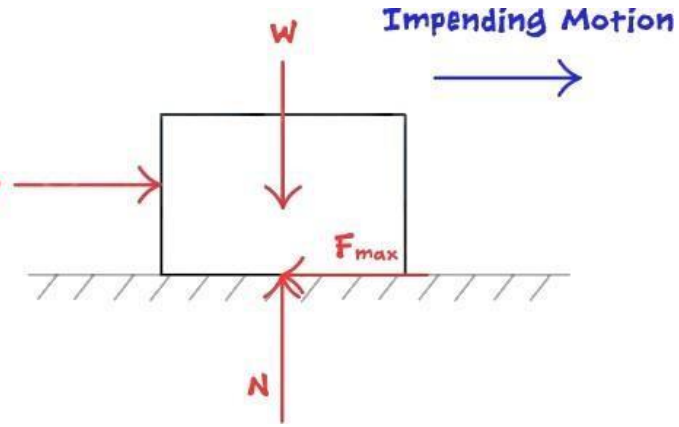


Rolling



FRICTION

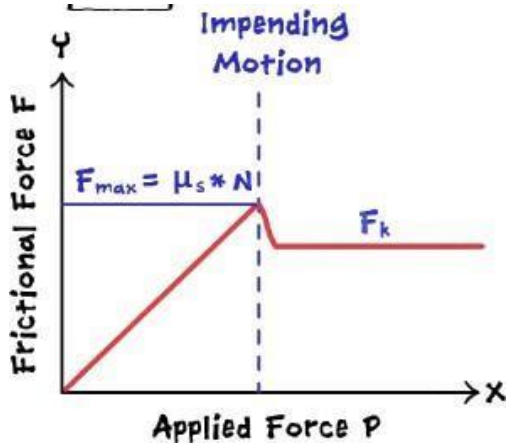
Law of Static Friction

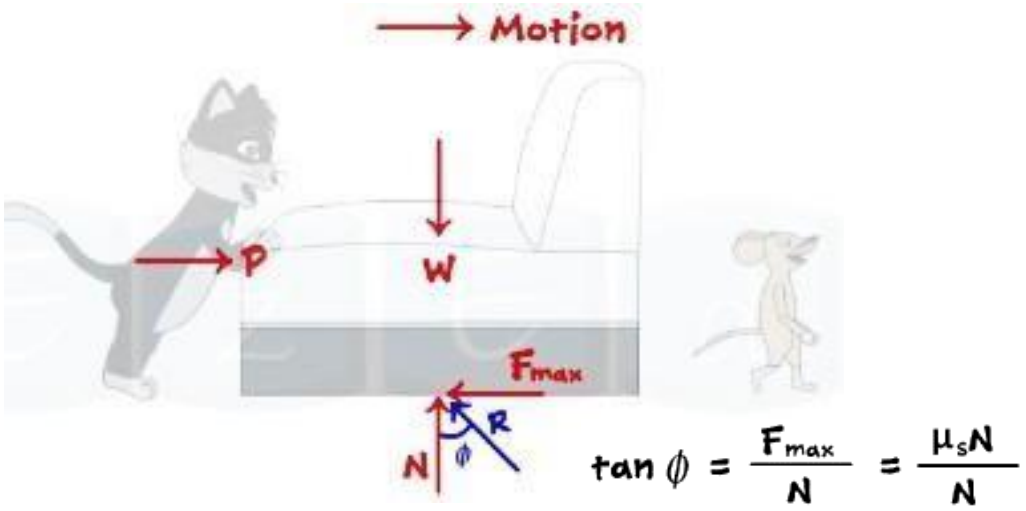


- The force of friction always acts in a direction, opposite to that in which the body tends to move.
- The magnitude of the force of friction is exactly equal to the applied force which just moves the body
- The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two surfaces in contact
- The force of friction is independent of the area of contact between the two surfaces.

Basic Terms in Friction

- **Limiting Friction** The maximum static friction after which the body will start moving is called limiting friction.

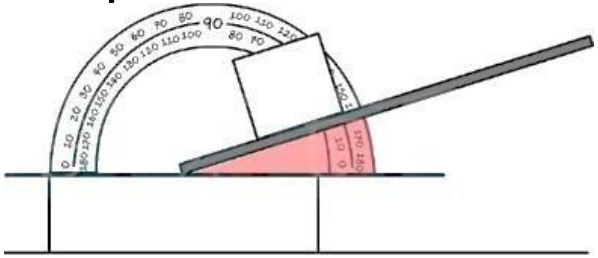




- **Angle of Friction** The angle of friction for two contacting surfaces is the angle between the resultant R (of friction force F and the normal reaction N) and the normal reaction N.

Basic Terms in Friction

- **Angle of Repose** The maximum angle made by the inclined plane with the horizontal, when the body placed on that plane is just at the point of sliding down the plane without any external force is known as the angle of repose



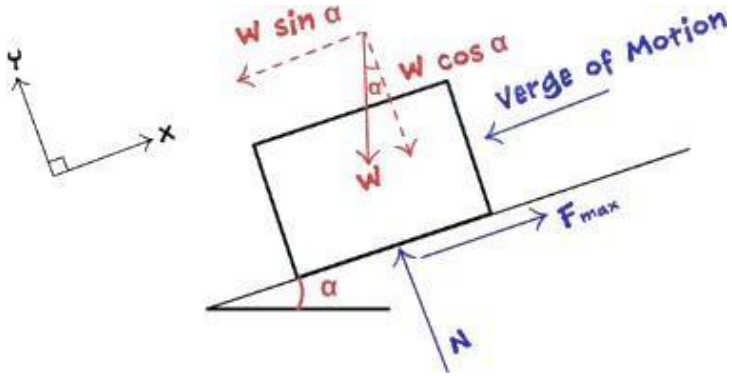
Apply COE

$$\mu_s N - W \sin\alpha = 0 \quad ....(i)$$

$$N = W \cos\alpha ....(ii)$$

$$\mu_s (W \cos\alpha) - W \sin\alpha = 0$$

$$\tan\alpha = \mu_s \qquad \alpha = \tan^{-1}\mu_s$$

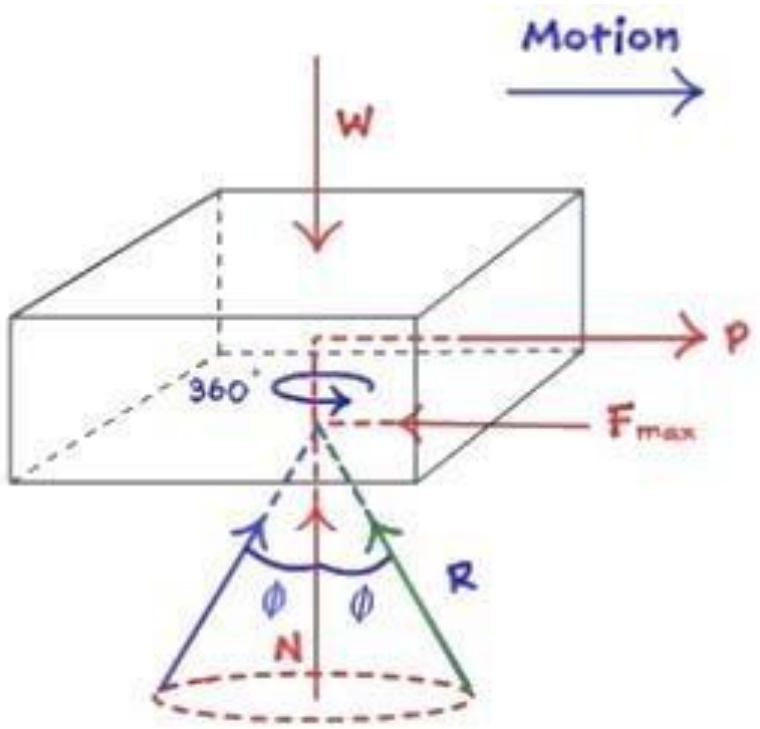


We know that, $\phi = \tan^{-1}\mu_s$

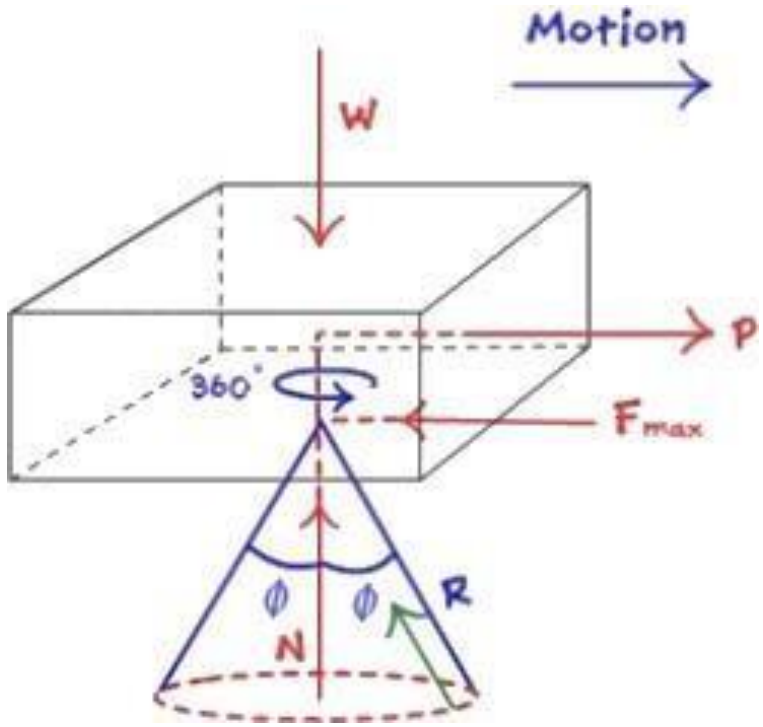
$$\alpha = \phi$$

Basic Terms in Friction

- **Cone of Friction**



Static body under verge of motion



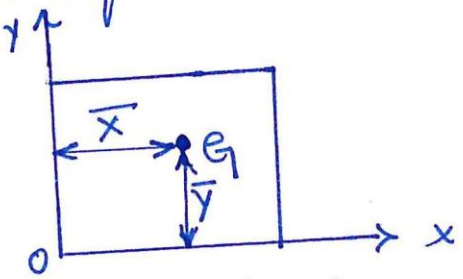
Static body under Equilibrium

Unit 5 → Centroid and Moment of Inertia

Centre of gravity → It is the point where the whole weight of the body is assumed to be concentrated. It is the point on which the body can be balanced. It is the point through which the weight of the body is assumed to act. This point is usually denoted by 'C.G' or 'G'

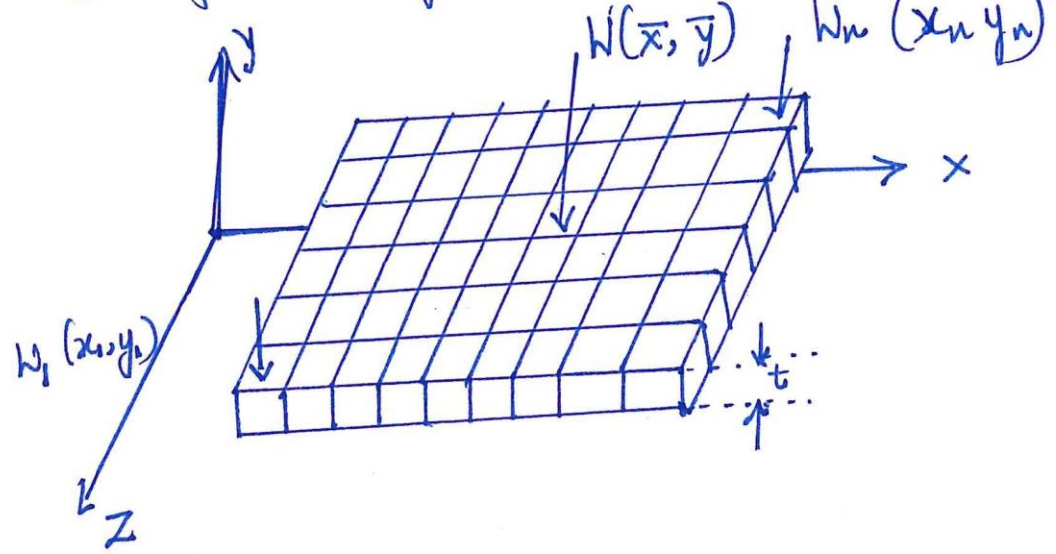
Centroid (C.G. or G)

Centroid is the point where the whole area of the plane figure is assumed to be concentrated. The determination of $\bar{x}$ and $\bar{y}$ is itself the calculation of centroid.



Determination of Centroid by the method of moments

Let us consider a body of total weight W as shown in the figure. The centre of gravity of the whole figure is located at a distance $\bar{x}$ from the y axis and at a distance $\bar{y}$ from the x axis (the point through which the total weight W acts)



Let us divide the whole figure into a number of elemental strips of weights $w_1, w_2, w_3, w_4, \ldots w_n$ whose centroids are located at distance $x_1, x_2, x_3, \ldots x_n$ from the y axis and $y_1, y_2, y_3 \ldots y_n$ from the x axis.

Applying the theorem of moments about the y-axis.

$$W\bar{x} = w_1x_1 + w_2x_2 + w_3x_3 + \cdots + w_nx_n$$

$$\text{or} \quad \bar{x} = \frac{w_1x_1 + w_2x_2 + w_3x_3 + \cdots w_nx_n}{W}$$

But if the body is homogeneous and isotropic, then the specific weight of the material is given by

$$\gamma = \frac{W}{V} = \frac{W}{Axt}$$

where W is the weight of the body and V is the volume of the body, A is the cross-sectional area and t is the thickness which is constant.

Hence we have

$$\bar{x} = \frac{\gamma a_1 t x_1 + \gamma a_2 t x_2 + \gamma a_3 t x_3 + \cdots \gamma a_n t x_n}{\gamma a_1 t + \gamma a_2 t + \gamma a_3 t + \cdots \gamma a_n t}$$

$$\bar{x} = \frac{\gamma t (a_1x_1 + a_2x_2 + a_3x_3 + \cdots a_nx_n)}{\gamma t (a_1 + a_2 + a_3 + \cdots a_n)}$$

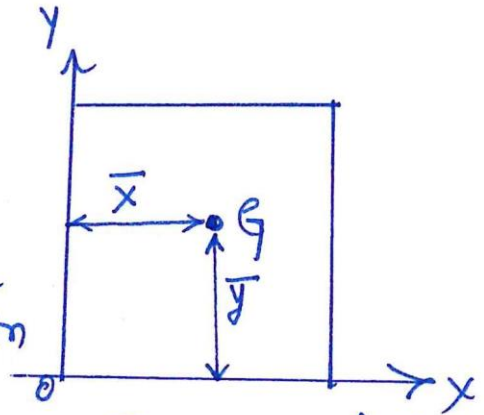
$$\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3 + \cdots a_nx_n}{a_1 + a_2 + a_3 + \cdots a_n}$$

$$\boxed{\bar{x} = \frac{\Sigma ax}{\Sigma a}}$$

Similarly $\boxed{\bar{y} = \frac{\Sigma ay}{\Sigma a}}$

Axes of Reference

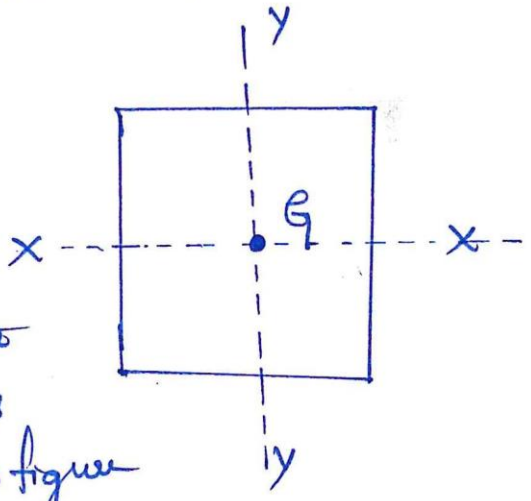
The axes with respect to which the centroid of a given figure is determined is called axes of reference.



Generally the left-hand bottom corner of the plane figure is considered as the origin so that the left extreme edge and the bottom line are considered reference axes, with respect to which the centroid of the given figure is determined.

Centroidal axis

The axis which passes through the centroid of the given figure is known as centroidal axis, such as x-x and y-y as shown in the figure.



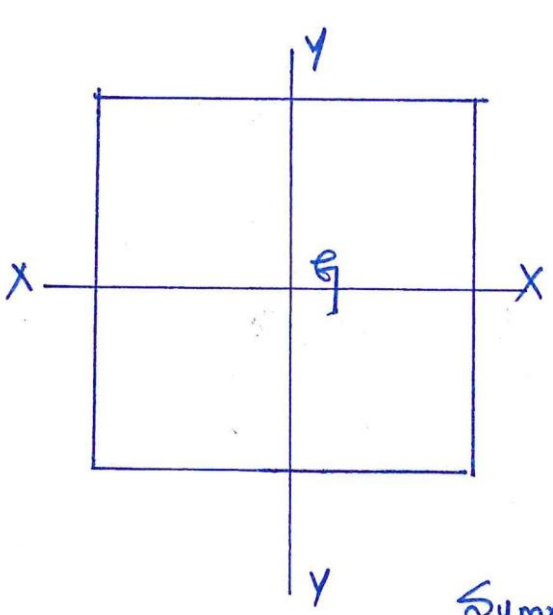
Symmetrical axis

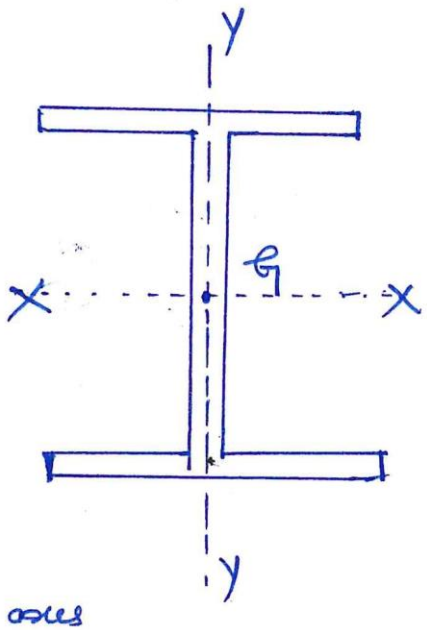
It is the axis which divides the whole figure into two equal parts, such as the x and x and y-y shown in figure

a) for a figure which is symmetrical about the both the axes
$\bar{x} = 0$ and $\bar{y} = 0$

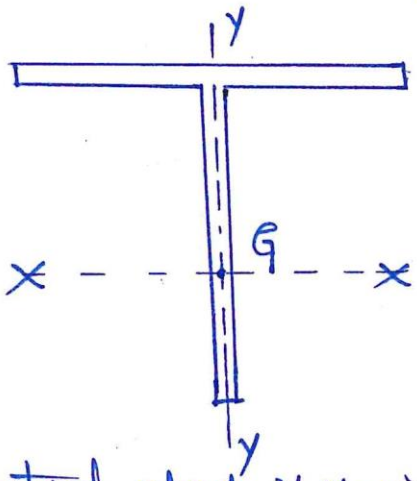
b) For a figure which is symmetrical about the Y-Y axis, $\bar{x} = 0$. Such a figure which is symmetrical about the Y-Y axis is shown in figure.
The area on the left side of the Y-Y axis is equal to the area on the right side of the Y-Y axis.

c) for a figure which is symmetrical about the X-X axis, $\bar{y} = 0$, Such a figure which is symmetrical about the X-X axis is shown in figure

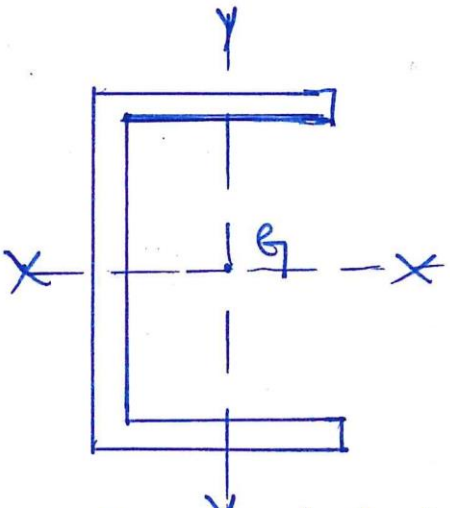




Symmetrical axes

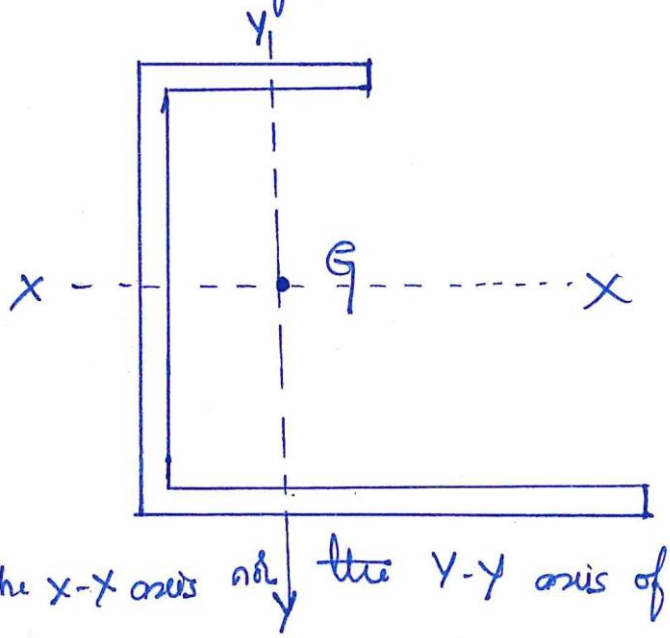


Symmetrical about Y-Y axis



Symmetrical about X-X axis

For a figure which doesn't have any axis of symmetry, we calculate both $\bar{x}$ and $\bar{y}$.



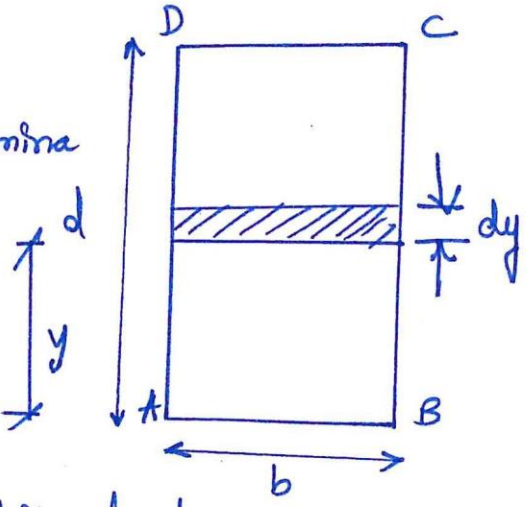
Neither the X-X axis nor the Y-Y axis of Symmetry

Derivation of Centroid of Some important geometrical figures

1) Rectangle

Let us Consider a rectangular lamina of area $b \times d$ as shown in the figure.

Now Consider a horizontal strip (Elementary strip) of area $b \times dy$, which is at a distance y from the reference axis AB.



Moment of area of elementary strip about AB

$= b \times dy \times y$ { area of an elementary strip $\times \perp^{r}$ dist to AB }

Sum of moments of such elementary strips about AB is given by

$$\int_0^d b \times dy \times y$$

$$= b \int_0^d y \cdot dy$$

$$= b \times \left[\frac{y^2}{2}\right]_0^d$$ { Integrating and applying the limits }

$$= b\left[\frac{d^2}{2} - \frac{0^2}{2}\right]$$

$$= \frac{bd^2}{2}$$

Moment of total area about $AB = bd \times \bar{y}$

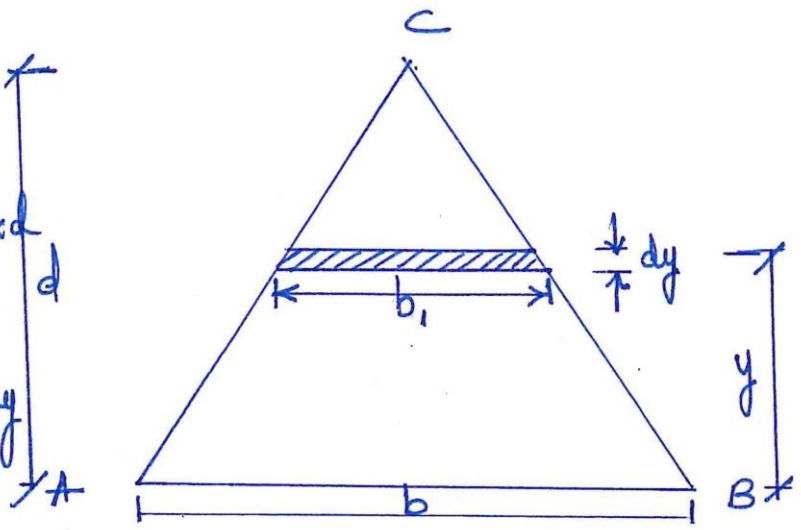
Apply the principle of moment about AB,

$$\frac{bd^2}{2} = bd \times \bar{y}$$

$$\Rightarrow \bar{y} = \frac{bd^2}{2bd} = d/2 \quad \therefore \boxed{\bar{y} = d/2}$$

By considering vertical strip, Similarly we can prooove that $\boxed{\bar{x} = b/2}$.

2) Triangle



Soln:-

Consider a triangular lamina of area $(1/2) \times b \times d$ as shown in the figure

Now Consider an elementary strip of area $b_1 \times dy$ which is at a distance y from the reference axis AB.

Using the property of similar Δles, we have

$$\frac{b_1}{b} = \frac{d-y}{d}$$

(or)

$$b_1 = \frac{(d-y)b}{d}$$

Area of the elementary strip is $= b_1 \times dy$

$$= \frac{(d-y)b}{d} \cdot dy$$

Area of the Elementary strip $= \frac{(d-y)\,b.\,dy}{d}$

Moment of area of Elementary strip about AB

$$= \text{area} \times y$$

$$= \frac{(d-y)b.\,dy.\,y}{d}$$

$$= \frac{b.dy.d.y}{d} - \frac{by^2.dy}{d}$$

$$= by.dy - \frac{by^2.dy}{d}$$

Sum of moments of such Elementary strips is given by

$$= \int_0^d by \cdot dy - \int_0^d \frac{by^2}{d} \cdot dy$$

$$= \left[\frac{by^2}{2}\right]_0^d - \left[\frac{by^3}{3d}\right]_0^d$$

$$= b\left[\frac{y^2}{2}\right]_0^d - \frac{b}{d}\left[\frac{y^3}{3}\right]_0^d$$

$$= \frac{bd^2}{2} - \frac{bd^3}{3d}$$

$$= \frac{bd^2}{2} - \frac{bd^2}{3}$$

$$= \frac{bd^2}{6}$$

Moment of total area about AB $= \frac{1}{2} \times b \times d \times \bar{y}$

Applying theorem of moments,

$$\frac{bd^2}{6} = \frac{1}{2} \times b \times d \times \bar{y}$$

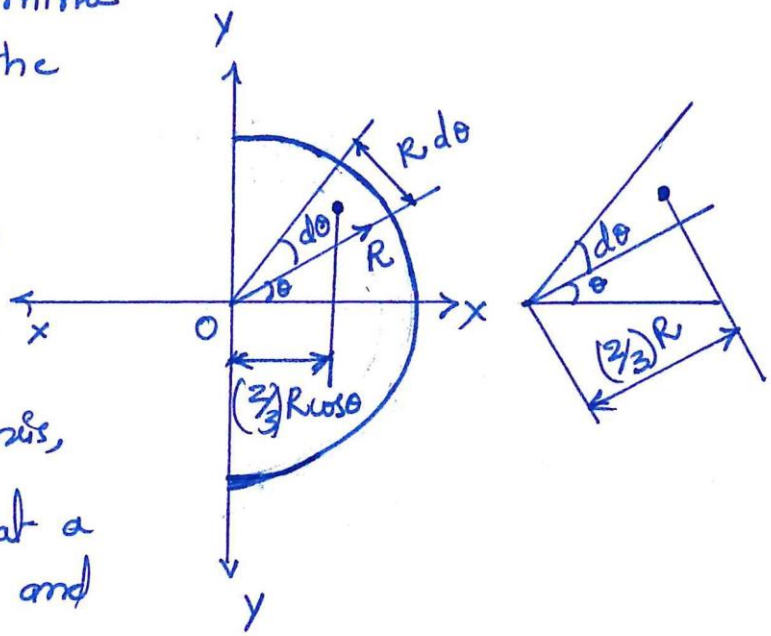
$$\bar{y} = \frac{2bd^2}{3bd}$$

$$\therefore \bar{y} = d/3$$

from the base AB.

3) Semi Circle

Consider a semicircular lamina of area $\frac{\pi r^2}{2}$ as shown in the figure.



Now Consider a triangular elementary strip of area $\frac{1}{2} \times R \times R \times d\theta$ at an angle of θ from the x axis, whose centre of gravity is at a distance of $\frac{2}{3}R$ from O and it's projection on the x axis $= \left(\frac{2}{3}\right) R \cos\theta$.

Moment of area of Elementary strip about the y axis

$$= \frac{1}{2} \times R^2 \times d\theta \times \left(\frac{2}{3}\right) R \cos\theta$$

$$= \frac{R^3 \cdot \cos\theta \cdot d\theta}{3}$$

Sum of moments of such elementary strips about the y axis

$$= \int_{-\pi/2}^{\pi/2} \frac{R^3 \cdot \cos\theta \cdot d\theta}{3}$$

$$= \frac{R^3}{3} \left(\sin\theta\right)_{-\pi/2}^{\pi/2}$$

$$= \frac{R^3}{3}\left[\sin \pi/2 - \sin\left(-\pi/2\right)\right] = \frac{R^3}{3}\left[\sin \pi/2 + \sin \pi/2\right]$$

$$= \frac{2R}{3}$$

Moment of total area about the y axis $= \frac{\pi R^2}{2} \times \bar{x}$

Using the principle of moments,

$$\frac{2R^3}{3} = \frac{\pi R^2}{2} \times \bar{x}$$

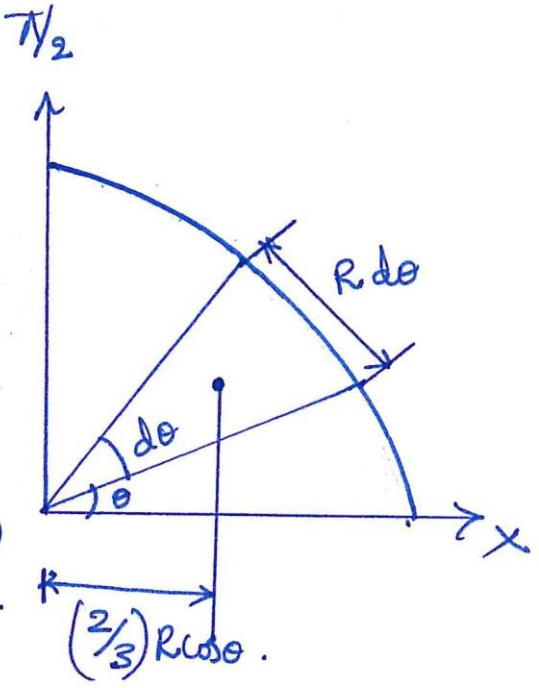
$$\bar{x} = \frac{2 \times 2R^3}{3 \pi R^2}$$

$$\boxed{\bar{x} = \frac{4R}{3\pi}}$$

4) Quarter Circle

Consider a quarter circular lamina of area $\frac{\pi R^2}{4}$ as shown in the figure.

Consider a ~~triangular~~ elementary strip of area $\frac{1}{2} \times R \times R \times d\theta$ at an angle of θ from the x axis, whose centre of gravity is at a distance of $\frac{2}{3}R$ from O and its projection on x axis $= \left(\frac{2}{3}\right) R\cos\theta$.



Moment of area of elementary strip about the y axis

$$= \frac{2}{3} R\cos\theta \times \frac{1}{2} \times R^2 \times d\theta$$

$$= \frac{R^3 \cdot \cos\theta \cdot d\theta}{3}$$

Sum of moments of such elementary strips about the y-axis

$$= \int_0^{\pi/2} \frac{R^3}{3} \cdot \cos\theta \cdot d\theta$$

$$= \frac{R^3}{3} \left[\sin\theta\right]_0^{\pi/2}$$

$$= \frac{R^3}{3} \left[\sin\frac{\pi}{2} - \sin 0\right]$$

$$= \frac{R^3}{3} //.$$

Moment of total area about the y axis

$$= \frac{\pi R^2}{4} \times \bar{x}$$

Using the principle of moments,

$$\frac{R^3}{3} = \frac{\pi R^2}{4} \times \bar{x}$$

$$\bar{x} = \frac{4R}{3\pi}$$

$$\boxed{\bar{x} = \frac{4R}{3\pi}}$$

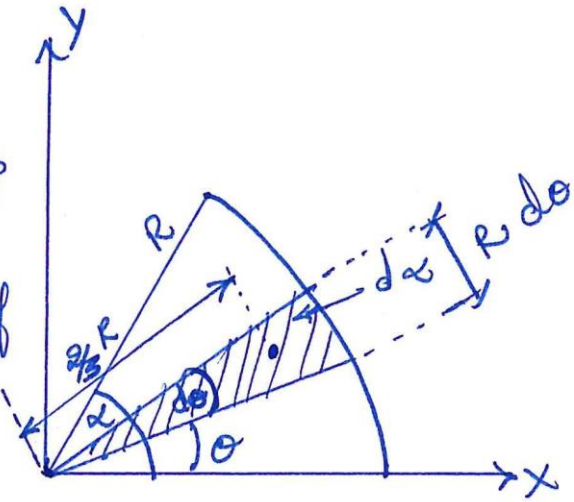
or Similarly, we can prove that $\boxed{\bar{y} = \frac{4R}{3\pi}}$

3) Sector of a Circle

Consider a sector of Circular lamina as shown in the figure.

Consider a triangular elementary strip of area $\frac{1}{2} \times R \times R\,d\theta$ at an angle of θ from the x axis, whose centre of gravity is at a distance of $\frac{2}{3}$ from O and its projection on x axis

$= \frac{2}{3} R\cos\theta$.



$$\text{Area of strip} = \frac{1}{2} \times R \times R\,d\theta = \frac{1}{2} R^2 d\theta$$

Area of sector is given by

$$\int_0^{\alpha} \frac{1}{2} \cdot R^2 \cdot d\theta = \frac{1}{2} \cdot R^2 [\theta]_0^{\alpha} = \frac{1}{2} R^2 \alpha$$

Moment of area of Elementary strip about y axis

$$= \frac{2}{3} R\cos\theta \times \frac{1}{2} \times R^2 \, d\theta$$

$$= \frac{R^3 . \cos\theta . d\theta}{3}$$

Sum of moments of such Elementary strips about y axis

$$= \int_0^{\alpha} \frac{R^3 . \cos\theta . d\theta}{3} = \frac{R^3}{3} \int_0^{\alpha} \cos\theta . d\theta$$

$$= R^3/3 \left[\sin\theta\right]_0^{\alpha} = R^3/3 \left[\sin\alpha - \sin 0\right]$$

$$= \frac{R^3}{3} \sin\alpha$$

Moment of total area about y - axis

$$= \frac{R^2 \alpha}{2} \times \bar{x}$$

Using the principle of moments

$$\frac{R^3}{3} \sin\alpha = \frac{R^2 \alpha}{2} \times \bar{x}$$

$$\bar{x} = \frac{2R^3 \sin\alpha}{3R^2 \alpha}$$

$$\bar{x} = \frac{2R}{3} \frac{\sin\alpha}{\alpha}$$

(or)

Moment of area of elementary strip about x axis

$$= \frac{2}{3} R\sin\theta \times \frac{1}{2} \times R^2 . d\theta = \frac{R^3 . \sin\theta . d\theta}{3}$$

Sum of moments of such Elementary strips about y axis

$$= \int_0^{\alpha} \frac{R^3}{3} \sin\theta . d\theta = \frac{R^3}{3} \left[-\cos\theta\right]_0^{\alpha} \quad \frac{R^3}{3} \left[-\cos\alpha - (-\cos 0)\right]$$

$$= \frac{R^3}{3} \left[1 - \cos\alpha\right]$$

Moment of total area about y axis $= \frac{R^2\alpha}{2} \times \bar{y}$

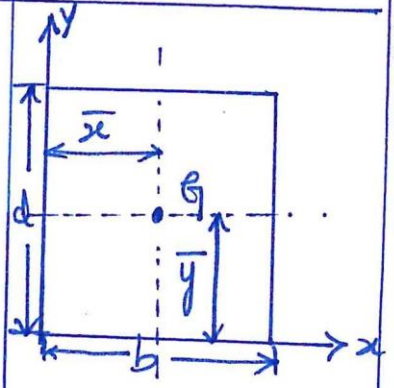
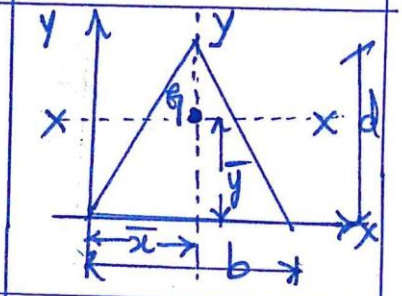
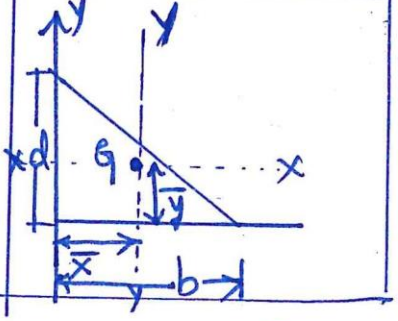
Using the principle of moments,

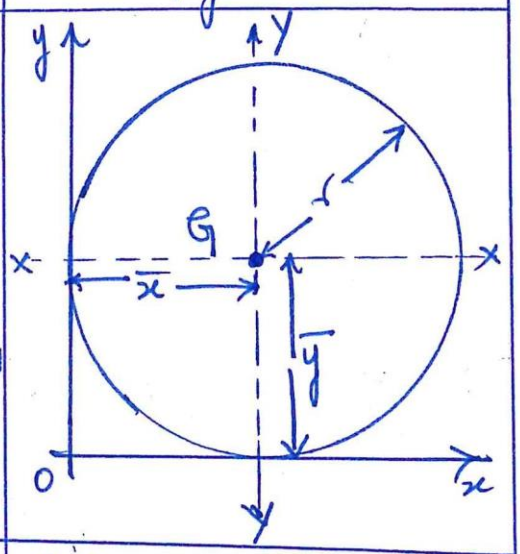
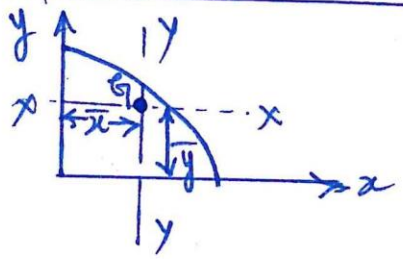
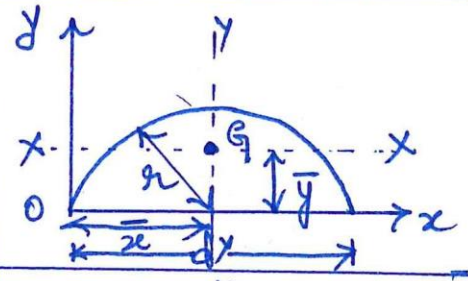
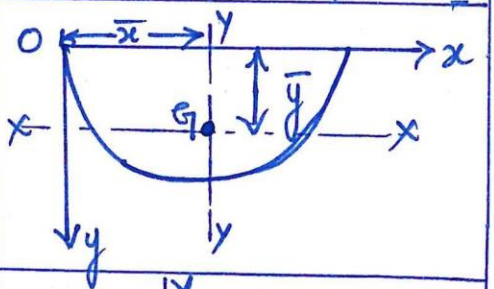
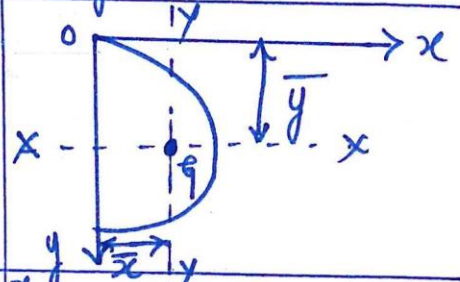
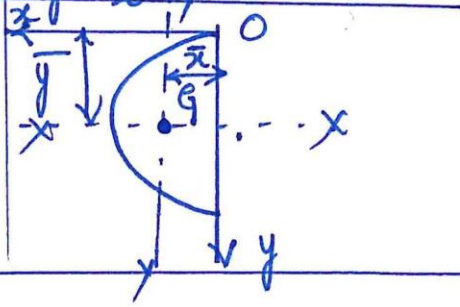
$$\frac{R^3}{3}(1-\cos\alpha) = \frac{R^2\alpha}{2} \times \bar{y}$$

$$\bar{y} = \frac{2R^3(1-\cos\alpha)}{3R^2\alpha}$$

$$\bar{y} = \frac{2R}{3}\left(\frac{1-\cos\alpha}{\alpha}\right)$$

Centroids of some important Geometrical figures

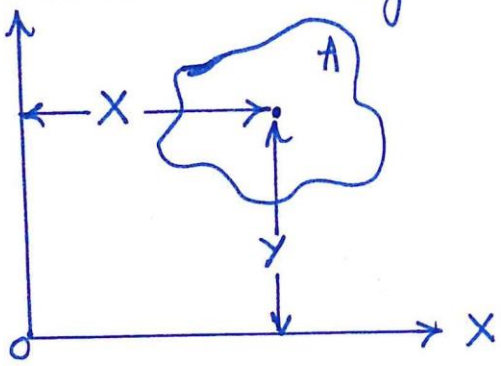
Shape	Area	$\bar{x}$	$\bar{y}$	figure
Rectangle (Same for Square)	b.d	$b/2$	$d/2$	
Triangle	$(1/2)$ b.d	$b/2$	$(1/3)$ d from base.	
Right angled Triangle	$(1/2)$ b d	$(1/3)$ b	$(1/3)$ d	

Shape	Area	$\bar{x}$	$\bar{y}$	figure
Circle	πr^2	$\bar{x} = r$	$\bar{y} = r$	
Quarter Circle	$\frac{\pi r^2}{4}$	$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$	
Semi Circle	$\frac{\pi R^2}{2}$	$d/2$	$\frac{4r}{3\pi}$	
		$d/2$	$-\frac{4r}{3\pi}$	
		$\frac{4r}{3\pi}$	$-d/2$	
		$-\frac{4r}{3\pi}$	$d/2$	

Unit 5 - Moment of Inertia

Introduction

Let us Consider an irregular plane lamina of area A, whose Centre of gravity is at distance x from the Reference Y-axis and at a distance y from Reference X axis as shown in the figure



Moment of area about the y-axis = first moment of area.

If the first moment of area is multiplied by the perpendicular distance x, it gives Ax^2 known as the

Second moment of area or moment of inertia.

Moment of inertia about y-axis, $I_{yy} = Ax^2$

Moment of inertia about x-axis, $I_{xx} = Ay^2$

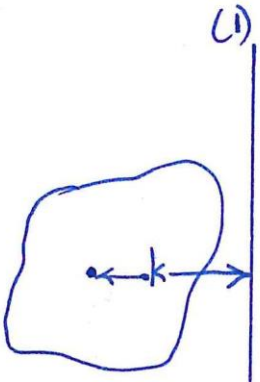
least and greatest moment of inertia

$\overline{I_x}$ and $\overline{I_y}$ are the moment of inertia of a plane figure about x-axis and y-axis. If $\overline{I_x}$ is greater than $\overline{I_y}$ then $\overline{I_x}$ is known as greatest moment of inertia and $\overline{I_y}$ is called the least moment of inertia.

The unit of moment of inertia is mm⁴ & m⁴.

Radius of gyration (k)

It is the distance from the given axis where the whole area of a plane figure is assumed to be Concentrated so as not to alter the moment of inertia about the given axis. for example, the moment of inertia about 1-1, refer to fig.



(1)

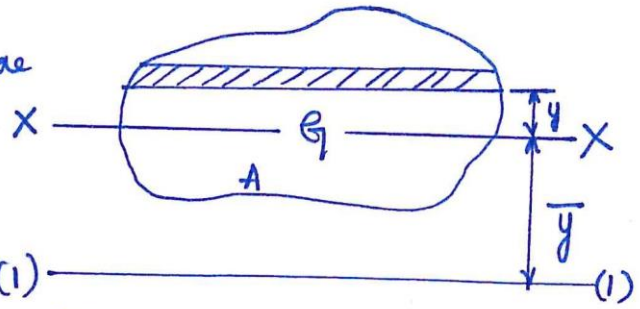
(1)

$I = Ak^2$ and hence $k = \sqrt{\frac{I}{A}}$

that is $k_x = \sqrt{\frac{I_x}{A}}$ and $k_y = \sqrt{\frac{I_y}{A}}$

Parallel Axis Theorem

This theorem states that the moment of inertia of plane figure about an axis I_{1-1}, parallel to the centroidal axis, $\bar{I}_x$ is equal to the sum of moment of inertia about centroidal axis i.e $\bar{I}_x$ and the product of area of the plane figure and square the distance between the two axes.



Proof:- Let us consider a plane figure of total area A as shown in figure. Let $\bar{I}_x$ be the moment of inertia about the x-axis and I_{1-1} the moment of inertia about 1-1 axis.

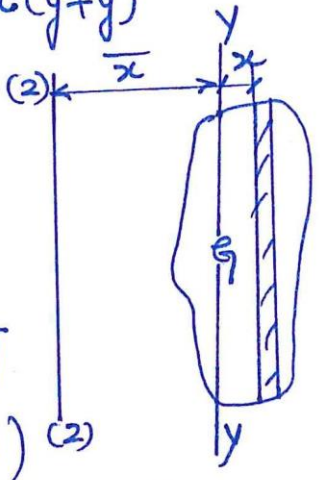
Let us choose an elementary strip of area da at a distance y from the centroidal axis.

Moment of inertia of the strip about the x-x axis $= da.y^2$

Moment of inertia of the total area about x-x axis $= \bar{I}_x = \Sigma da.y^2$

Moment of inertia of the strip about 1-1 axis $= da.(y+\bar{y})^2$

Moment of inertia of the total area about 1-1 axis



$$I_{1-1} = \Sigma da.(y+\bar{y})^2$$

$$I_{1-1} = \Sigma da(y^2+\bar{y}^2+2y\bar{y})$$

$$I_{1-1} = \Sigma day^2 + \Sigma da\bar{y}^2 + \Sigma da.2y\bar{y}$$

$$I_{1-1} = \Sigma day^2 + \Sigma da\,\bar{y}^2 + 2\bar{y}(\Sigma da.y)$$

As the distance of C.G of whole area from the centroidal axis $=0$ i.e $y=0$, we get

$$\boxed{I_{1-1} = \bar{I}_x + A\bar{y}^2}$$

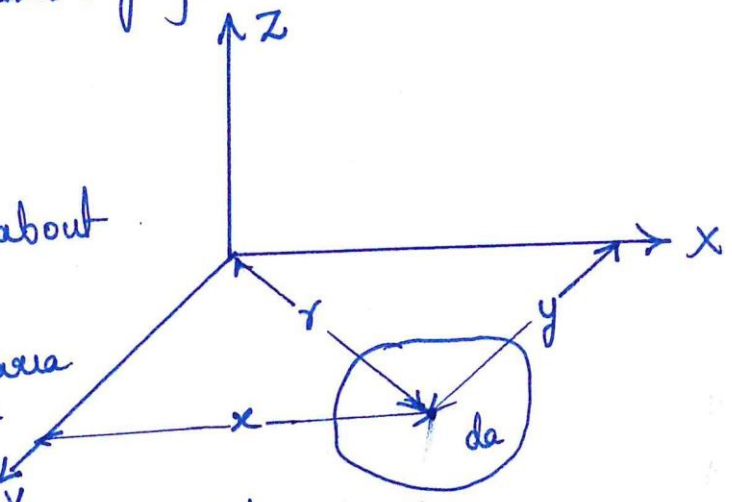
Similarly the moment of inertia about an axis I_{2-2} as shown in fig 2 is given by $\boxed{I_{2-2} = \bar{I}_y + A\bar{x}^2}$

Perpendicular axis theorem

This theorem states that moment of inertia of a plane figure about an axis which is perpendicular to the plane of the figure is equal to the sum of moment of inertia about two mutually perpendicular axes.

Proof

Let us Consider an Irregular figure of total area A as shown in figure. Let us choose an elemental strip of area da at a distance x from y axis, y from x axis and r from z axis, Respectively.



Then, $r^2 = x^2 + y^2$

Moment of inertia of the strip about x-axis $= da \times y^2$

Moment of inertia of the whole area about the x-axis $= \bar{I}_x = \sum da.y^2$

Similarly, moment of inertia of the strip about y-axis $= da.x^2$

Moment of inertia of the whole area about the y-axis $= \bar{I}_y = \sum da.x^2$

Moment of inertia of the strip about z-axis $= da \times r^2$

Moment of inertia of the whole area about z-axis $= \sum da.r^2$

$$= \sum da\,(x^2+y^2)$$

$$= \sum da.x^2 + \sum da.y^2$$

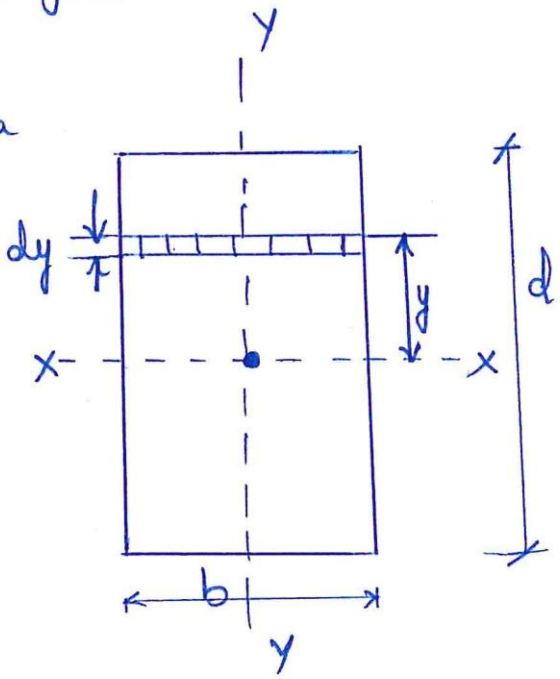
$$= \bar{I}_y + \bar{I}_x$$

$$\boxed{\bar{I}_z = \bar{I}_x + \bar{I}_y}$$

Moment of Inertia of Important figures

1) Rectangle

Let us Consider a rectangular lamina of breadth b and depth d whose moment of inertia to be determined. Now Consider an elementary strip of area b.dy at a distance y from the centroidal axis x-x.



The moment of inertia of the strip about the x-x axis $= b.dy \times y^2$.

Moment of inertia of the whole figure about the x-x axis

$$= \int_{-d/2}^{d/2} b.dy.y^2$$

$$= b\left[\frac{y^3}{3}\right]_{-d/2}^{d/2}$$

$$= b\left[\frac{d^3}{24} + \frac{d^3}{24}\right]$$

$$= b\left[\frac{2d^3}{24}\right]^{12}$$

$$\boxed{\overline{I_x} = \frac{bd^3}{12}}$$

Similarly $\boxed{\overline{I_y} = \frac{db^3}{12}}$

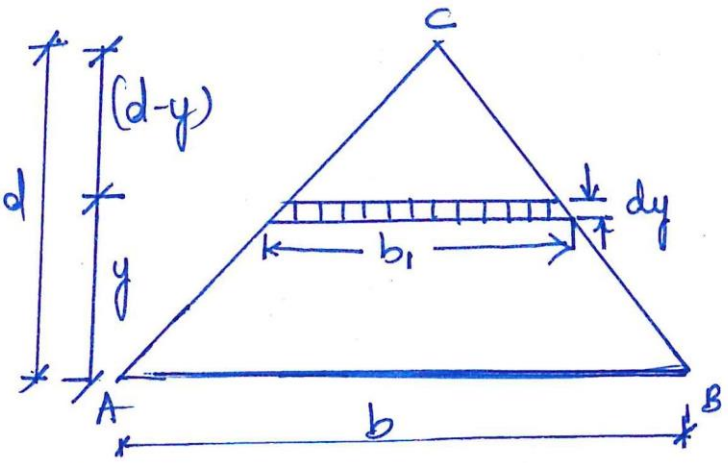
2) Triangle

Let us Consider a triangular lamina of base b and depth d as shown in figure. Let us Consider an elementary strip of area $b_1 \times dy$ which is @ distance y from base AB.

Using the property of similar $\triangle$les

$$\frac{b_1}{b} = \frac{d-y}{d}$$

$$b_1 = \frac{(d-y)b}{d}$$



Area of the strip $= \frac{(d-y)\,b}{d} \cdot dy$

Mome of inertia of the strip about AB $= \frac{(d-y)b}{d} \cdot dy \times y^2$

$$= \frac{bdy^2 \cdot dy}{d} - \frac{by^3 \cdot dy}{d}$$

$$= by^2 \cdot dy - \frac{by^3 \cdot dy}{d}$$

Moment of inertia of whole area about AB,

$$I_{AB} = \int_0^d by^2 dy - \frac{by^3 \cdot dy}{d}$$

$$= b\left[\frac{y^3}{3}\right]_0^d - \frac{b}{d}\left[\frac{y^4}{4}\right]_0^d$$

$$= \frac{bd^3}{3} - \frac{bd^4}{4d}$$

$$= \frac{bd^3}{3} - \frac{bd^3}{4}$$

$$I_{AB} = \frac{bd^3}{12}$$

Moment of inertia about x-x axis is given by

$$I_{AB} = \bar{I}_x + Ay^2$$

$$\bar{I}_x = I_{AB} - Ay^2$$

Prabhu HS

$$\overline{I_x} = \frac{bd^3}{12} - \frac{1}{2}b\cdot d\left(\frac{1}{3}d\right)^2 = \frac{bd^3}{36}$$

i.e $\boxed{\overline{I_x} = \frac{bd^3}{36}}$

∴ The moment of inertia of the triangle about the centroidal axis y-y is $= \boxed{\overline{I_y} = \frac{db^3}{36}}$

2) Circle

Let us consider a circular lamina of radius R as shown in figure

Let us choose a circular elementary strip of thickness dx at distance x from the centre.

Area of the strip $= 2\pi x \cdot dx$

Moment of inertia about the z-z axis

$= 2\pi x \cdot dx \cdot x^2$

Moment of inertia about the z-z axis for whole circle

$$= \overline{I_z} = \int_0^R 2\pi x^3 \cdot dx$$

$$\overline{I_z} = 2\pi\left[\frac{x^4}{4}\right]_0^R = \frac{2\pi R^4}{4} = \frac{\pi R^4}{2}$$

For circular lamina $\overline{I_x} = \overline{I_y}$

∴ Using $\perp^R$ axis theorem, we have $\overline{I_z} = \overline{I_x} + \overline{I_y}$

$$\overline{I_z} = 2\overline{I_x}$$

$$\overline{I_x} = \frac{\overline{I_z}}{2}$$

$$\overline{I_x} = \frac{\pi R^4}{2\times 2} = \frac{\pi R^4}{4}$$

$$\boxed{\overline{I_x} = \overline{I_y} = \frac{\pi R^4}{4}}$$

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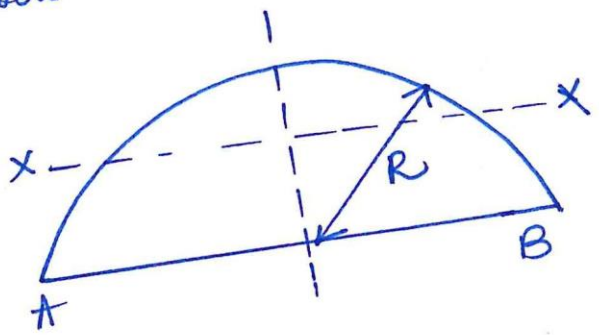
Semi Circle.

Let us Consider a semicircular Lamina of radius R as shown in figure



Moment of inertia of semicircle about the diametrical axis AB

$$= \frac{1}{2} \times \frac{\pi R^4}{4}$$

$$= \frac{\pi R^4}{8}$$

$$I_{AB} = \bar{I}_x + A\bar{y}^2$$

$$\bar{I}_x = I_{AB} - \frac{\pi R^2}{2}\left(\frac{4R}{3\pi}\right)^2$$

$$= \frac{\pi R^4}{8} - \frac{\pi R^2 \times 16R^2}{2 \times 9\pi^2}$$

$$= \frac{\pi R^4}{8} - \frac{8\pi R^4}{9\pi^2}$$

$$= \frac{\pi R^4}{8} - \frac{8R^4}{9\pi}$$

$$\boxed{\bar{I}_x = 0.11R^4}$$

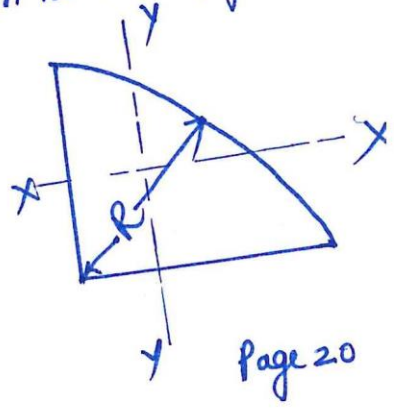
∴ Moment of inertia about the y-axis,

$$\bar{I}_y = \frac{\pi R^4}{8} = \frac{1}{2} \times \frac{\pi R^4}{4}$$

4) Quarter circle

For a quarter circle of radius R as shown in the figure

$$\bar{I}_x = \bar{I}_y = \frac{0.11R^4}{2} = \underline{0.055R^4}$$



Friction

10.1 Introduction

In the earlier chapters, we have assumed that the surfaces of contact between the bodies are smooth and at these points of contact there will be only a normal or perpendicular reaction acting to the surface.

In practice, every surface have minute projecting particles. When the surfaces are in contact then the projections interlock each other at the surfaces in contact. When such surfaces tend to move, the interlocking of projections resists the movement in the tangential direction and the resistance increases as shown in figure 10.1.

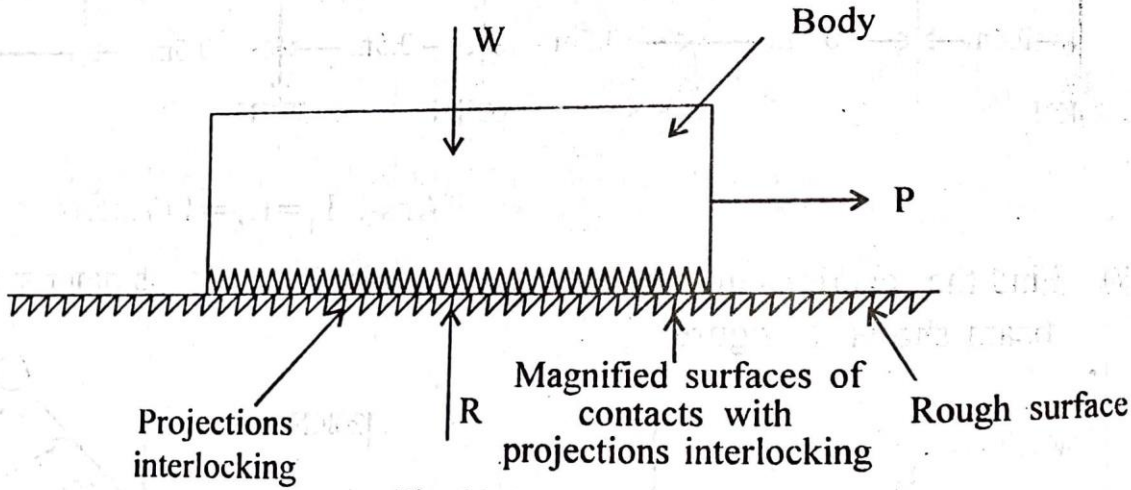


Fig. 10.1

With the increase in projections i.e., more the surface is rough, then more is the resistance.

10.2 Definition of Friction

When one body tends to move in contact over other body a resistance to its movement is set-up. This resistance to movement is called *Friction* or Force of Friction or Frictional Force.

The Force of Friction always acts in the direction opposite to the '*motion trend*' as shown in figure 10.2.

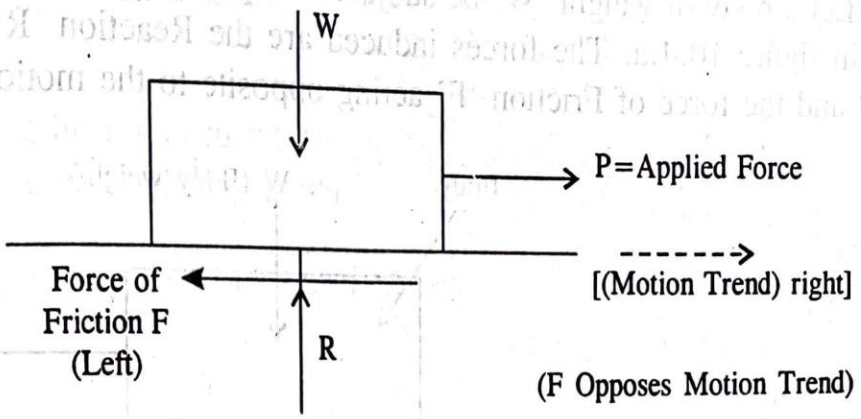


Fig. 10.2

10.3 Types of Friction

The various types of friction are :

1) **Static Friction :** The friction acting on a body which is at rest is called static friction.

2) **Limiting Friction :** The friction acting on a body which is just on the point or verge of sliding is called limiting friction.

3) **Dynamical Friction :** The friction acting on a body which is actually in motion is called Dynamical friction or Kinetic friction.

4) **Dry Friction :** The friction acting on a body when the contact surfaces are dry (i.e., unlubricated) and there is tendency of relative motion is called *Dry Friction* or Coulomb friction.

   Dry Friction is further divided into two types :

   a) **Solid Friction :** The friction acting on a body when two surfaces have tendency to slide relative to each other is called Solid friction (Figure 10.2).

   b) **Rolling Friction :** The friction acting on a body due to rolling of one surface over another is called Rolling friction.

5) **Fluid Friction :** The friction acting on a body when the contact surfaces are lubricated is called *Fluid friction.*

   Fluid friction is further divided into :

   a) **Skin or greasy or Non-Viscous friction :** The friction acting on a body when the contact surfaces are lubricated with extremely thin layer of lubricant is called Skin or greasy or Non-viscous Friction also called *Boundary Friction.*

   b) **Viscous or Film Friction :** The friction acting on a body when the contact surfaces are completely separated by lubricant is called *Viscous or Film friction.*

10.4 Motion Trend of a Block on Surface

Let a body of weight 'W' be subjected to pull 'P' which tend to move towards right as shown in figure 10.4.a. The forces induced are the Reaction 'R' acting perpendicular to the support and the force of Friction 'F' acting opposite to the motion trend.

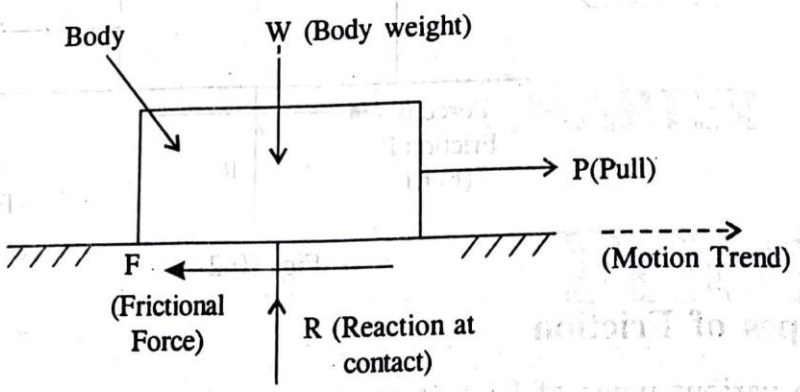


Fig. 10.4.a.

From figure 10.4.(b) you can see that the normal reaction and friction acting perpendicular to each other can be replaced by a single Resultant Reaction 'R_1' making angle 'φ'. So that,

$$\text{Tan}\varphi = \frac{F}{R} \qquad \text{.....(10.1)}$$

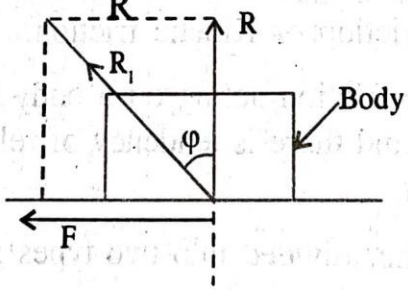


Fig. 10.4.b

10.5 Angle of Friction

The angle which the Resultant Reaction R_1 due to normal Reaction R and Friction F makes with the normal to the surface is called Angle of Friction (φ). In figure 10.4.b.

$$\boxed{\text{Tan}\varphi = \frac{F}{R}} \qquad \text{.....(10.2)}$$

10.6 Co-efficient of Friction (μ)

It is the ratio of the limiting friction F to the normal reaction R between two surfaces. This is also equal to the Tangent of angle of friction.

$$\mu = \frac{F}{R}$$

$$\therefore \text{Tan}\varphi = \mu = \frac{F}{R}$$ .....remember .....(10.3)

10.7 Angle of Repose

In figure 10.7, if a body is placed on an inclined plane, then the angle at which the body is just on the point or verge of sliding down is called Angle of Repose.

Angle of repose (α) = Angle of Limiting Friction (φ).

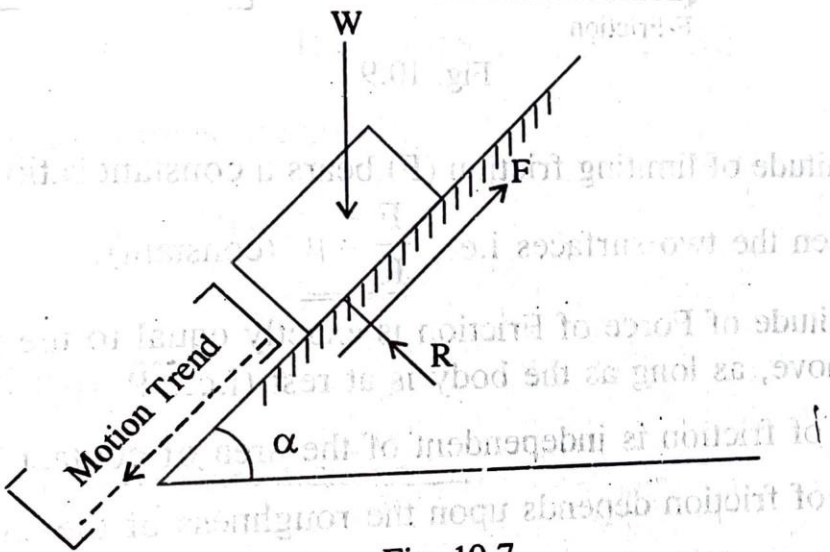
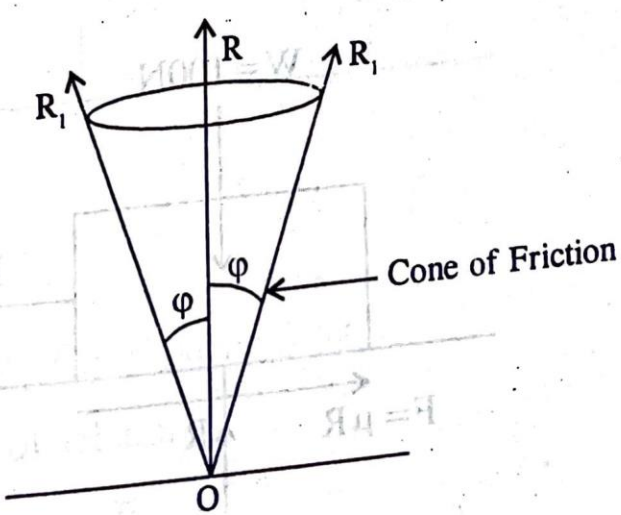


Fig. 10.7

10.8 Cone of Friction

Whenever a body in contact with other tend to move, then the normal reaction OR and Friction come into play. The normal reaction and Friction can be replaced by resultant reaction OR_1. When this resultant reaction OR_1 making angle is revolved around point O, will form a right circular cone.

This cone having the point of contact as the vertex O, the normal OR at the point of contact as its axis and φ as the semi-vertex angle is called the Cone of Friction (Fig. 10.8).



10.9 Laws of Dry Friction

1. The Force of Friction always acts in the direction opposite to that in which the body tends to move.

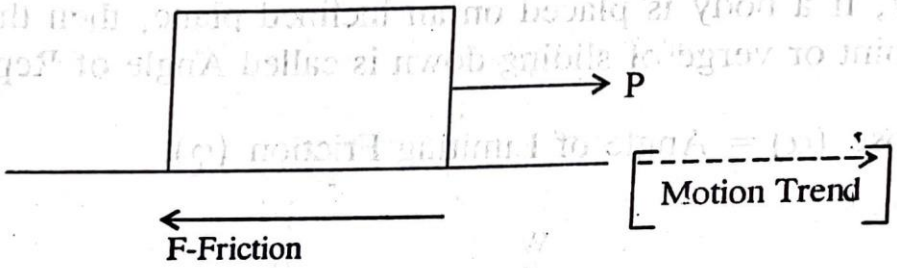


Fig. 10.9

2. The magnitude of limiting friction (F) bears a constant ratio to the normal reaction (R) between the two surfaces i.e., $\frac{F}{R} = \mu$ (constant).
3. The magnitude of Force of Friction is exactly equal to the force, which tends the body to move, as long as the body is at rest (i.e., $P = F$).
4. The force of friction is independent of the area of contact between two surfaces.
5. The force of friction depends upon the roughness of the surfaces in contact.

Cone of Friction

The combination of resultant R of frictional force F and normal reaction N obtained by applying forces in opposite directions successively form a right circular cone of angle 2ϕ, known as the cone of friction, as shown in Figure 8.5.

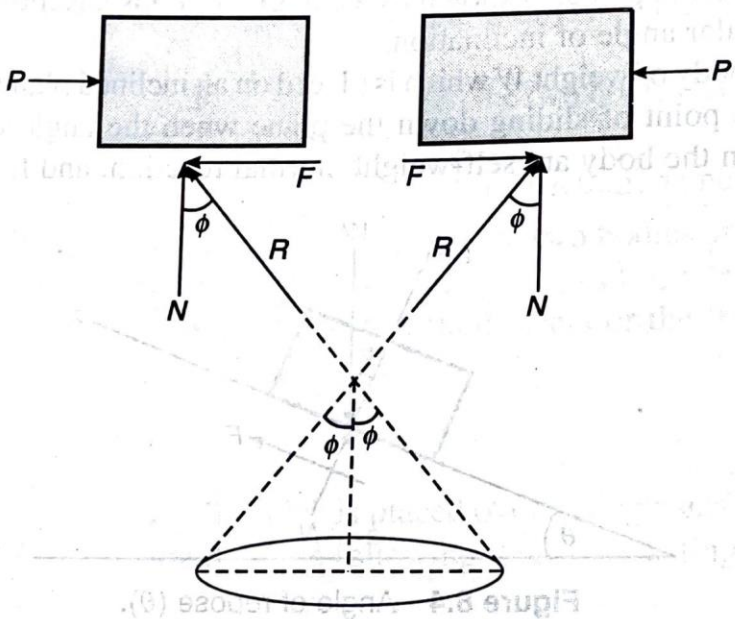


Figure 8.5 Cone of friction.

LAWS OF FRICTION

The laws of static friction are:

(i) The force of friction always acts in a direction, opposite to that in which the body tends to move.

(ii) The magnitude of the force of friction is exactly equal to the applied force which just moves the body.

(iii) The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two surfaces in contact, i.e.

$$\frac{F}{N} = \text{constant}$$

where F is the limiting friction and N is the normal reaction.

(iv) The force of friction is independent of the area of contact between the two surfaces.

(v) The force of friction depends upon the roughness of the surfaces in contact.

The laws of dynamic friction are:

(i) The force of friction always acts in a direction, opposite to that in which the body is moving.

(ii) The magnitude of the kinetic friction bears a constant ratio to the normal reaction between the two surfaces in contact. But this ratio is slightly less than that in the case of limiting friction.

(iii) The friction force remains constant for moderate speeds but decreases slightly with the increase in speed.

Angle of Repose (θ)

When a plane is inclined to the horizontal by a certain angle, the body placed on it will remain at rest up to a certain angle of inclination, beyond which the body just begins to move. This maximum angle made by the inclined plane with the horizontal, when the body placed on that plane is just at the point of sliding down the plane, is known as the angle of repose. Repose means sleep which is disturbed at that particular angle of inclination.

Let us consider a body of weight W which is placed on an inclined plane as shown in Figure 8.4. The body is just at the point of sliding down the plane when the angle of inclination is θ. The various forces acting on the body are self-weight, normal reaction, and frictional force.

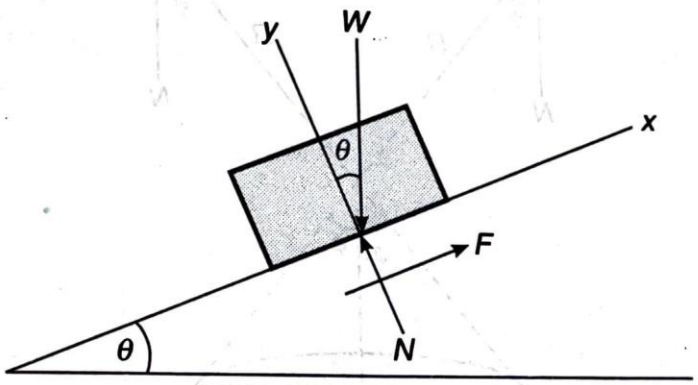


Figure 8.4 Angle of repose (θ).

Applying the conditions of equilibrium,

$$\Sigma F_x = 0;\ \Sigma F_y = 0$$

Resolving forces along the x-axis,

$$-F + W \sin\theta = 0$$

$$F = W \sin\theta \tag{8.2}$$

or

Resolving forces along the y-axis,

$$N - W\cos\theta = 0$$

$$N = W\cos\theta \tag{8.3}$$

or

We know that

$$\mu = \frac{F}{N}$$

$$\mu = \frac{W\sin\theta}{W\cos\theta} = \tan\theta \tag{8.4}$$

$\Rightarrow$

$$\tan\phi = \tan\theta$$

or

$$\phi = \theta$$

or

It is evident from Eqs. (8.1) and (8.4) that

Angle of friction = Angle of repose

Support and Support Reaction

9.1 Introduction

Every engineering structure needs to be supported, so that, it can remain in equilibrium under any system of forces (called Action) likely to act on it. These supports develop the force as *support reaction.*

Figure 9.1 shows a beam AB carrying loads (action) supported on the walls, which tend to push the walls down. Since the walls are rigid, will resist the downward push. The walls will exert upward forces called reactions.

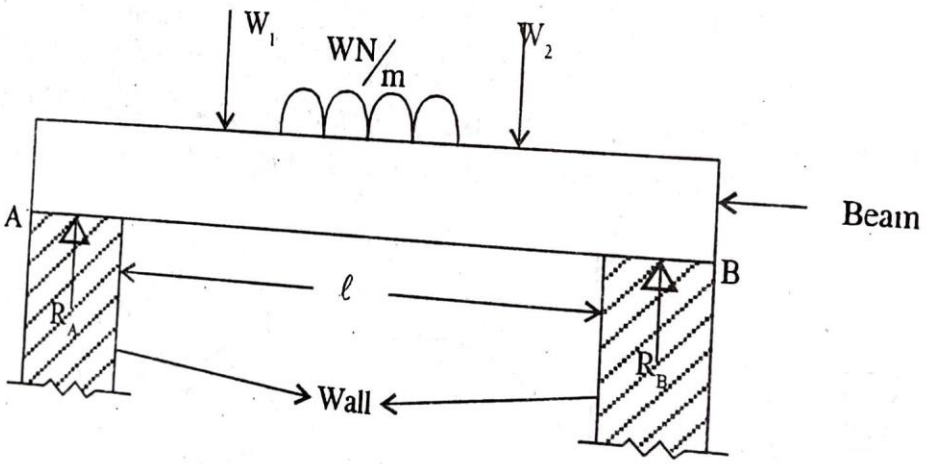


Figure 9.1

Actions are equal and opposite to reactions.

9.2 Support Reactions

Definition : When a number of forces are acting on a beam (called Action) then the support of the beam will provide the reactions called support reaction (R_A and R_B).

R_A and R_B along with loads will keep the system in equilibrium ($\Sigma H = \Sigma V = \Sigma M = 0$).

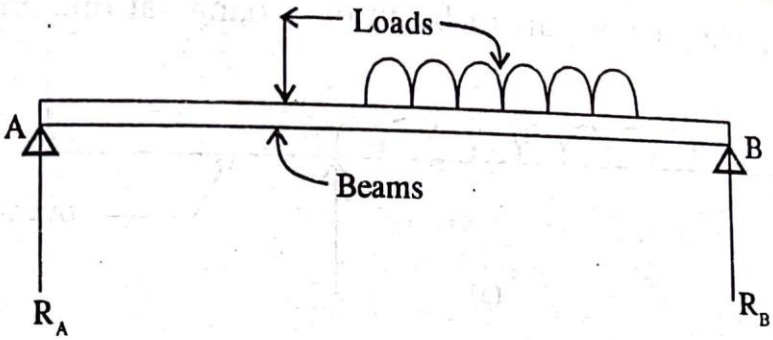


Fig. 9.2

9.3 Types of Beams

Beams are structural members having larger length compared to the width and depth subjected to system of load. Beams are of following types :

1) **Cantilever Beam :** One end of the beam is fixed and the other end is free.

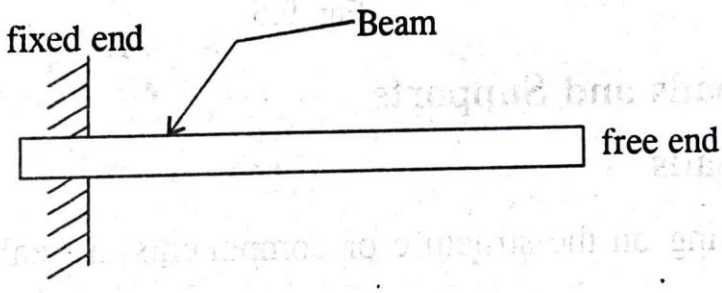
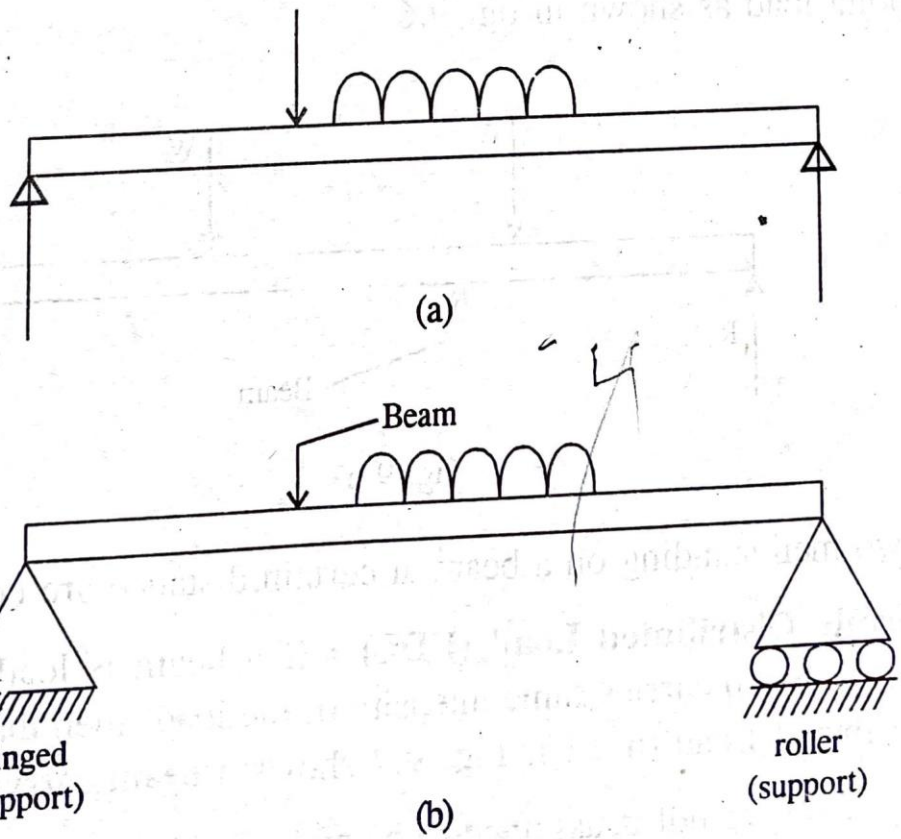


Fig. 9.3

2) **Simply Supported Beam :** Both ends of the beam are simply supported.



3) **Over hanging Beam :** A part of beam over hangs at one end or both ends.

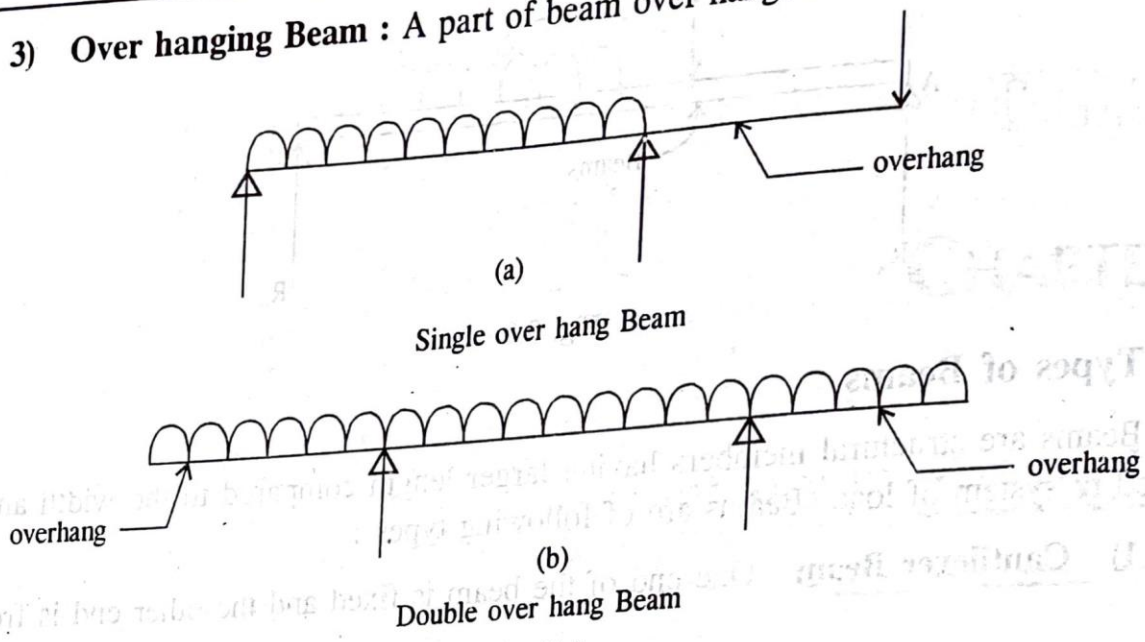


Fig. 9.5

9.4 Types of Loads and Supports

9.4.1 Types of Loads

The forces acting on the structure or components are called loads.

There are many types of loads like live load, dead load, wind load, earthquake load, yet the following are the important types of loads.

1) **Concentrated or point load :** A load acting at a point on a beam is known as concentrated or point load as shown in fig. 9.6

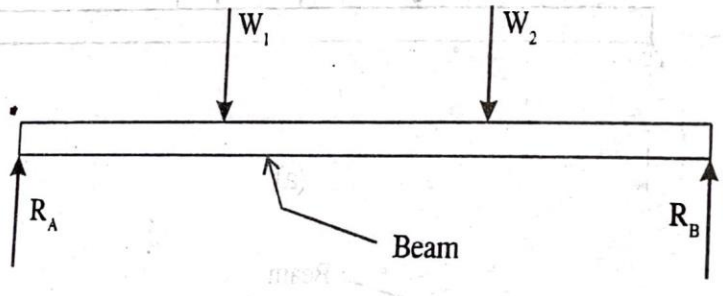


Fig. 9.6

For e.g. two men standing on a beam at certain distance are considered as point load.

2) **Uniformly Distributed Load (UDL) :** If a beam is loaded in such a way that, each unit length of the beam carries same intensity of the load, then that type of load is known as Uniformly Distributed Load (u.d.l.). Fig. 9.7 shows a beam carrying UDL.

The total laod due to udl is assumed to be acting at the centre of gravity of the *udl* for all calculations.

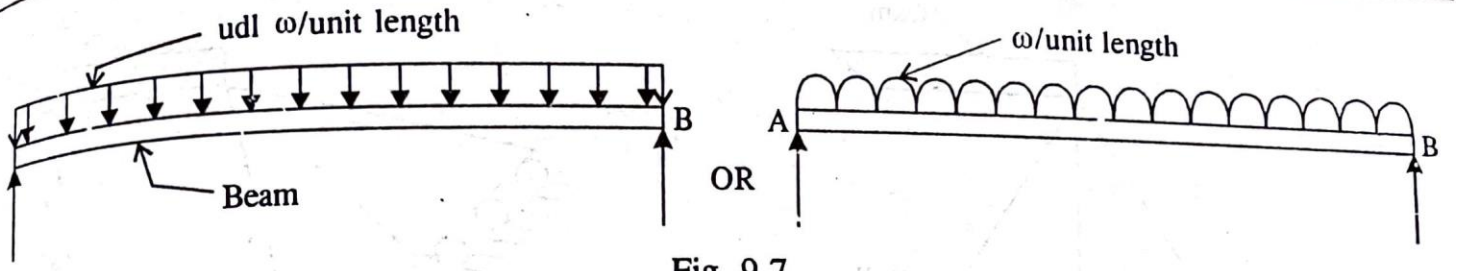


Fig. 9.7

In practice, a Brickwall constructed on a beam can be considered as the u.d.l.

3) Uniformly Varying Load : If a beam is loaded in such a way that, each unit length of the beam carries a uniformly varying intensity of loading (say w_1 at one end of w_2 at other end), then this type of loading is known as uniformly varying load as shown in fig. 9.8.

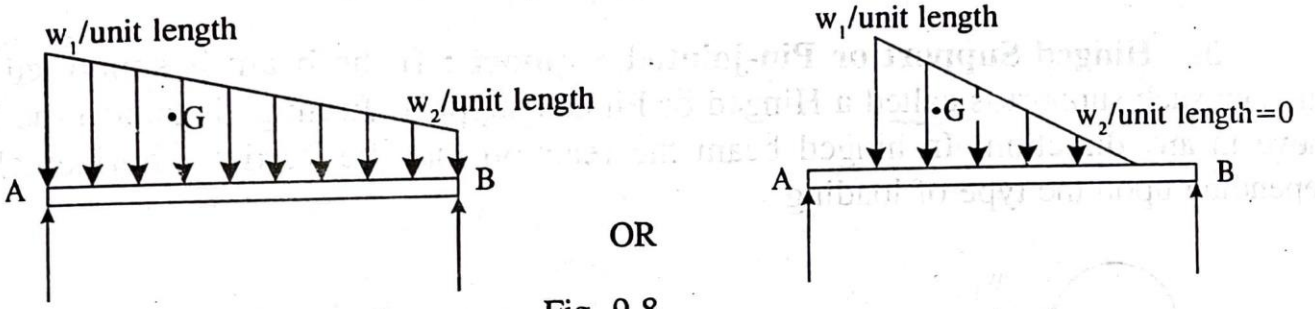


Fig. 9.8

The total load due to uniformly varying load is equal to the area of load diagram and is assumed to be acting at the centre of gravity (G) of the uniformly varying load for all calculations.

In practice, a brickwall constructed on a beam to carry pitched or sloping roof.

9.4.2 Types of Support

There are many types of supports and reactions as listed below :

1) Simple Support or Knife Edge Support : If the beam rests simply on a support then the support is *simple support*. In simple support the reactions at the support are at right angles or $\perp^{ar}$ to the beam.

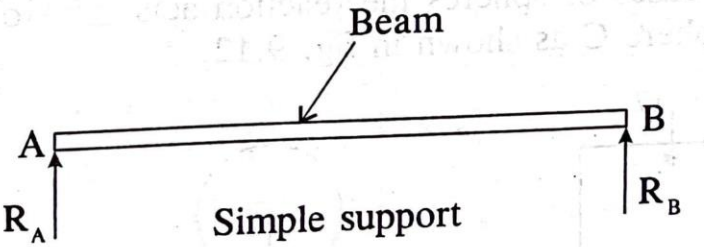
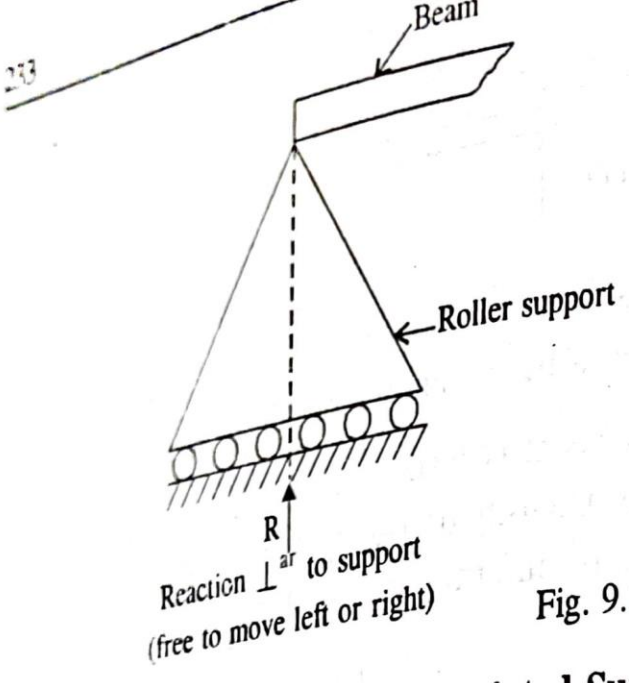


Fig. 9.9

2) Roller Support : If the beam is supported on rollers, then such a support is called a *roller support*. In roller support the reaction always acts at *right angles* or perpendicular to support surface. In the roller support the beam is free to roll left and right or up and down.



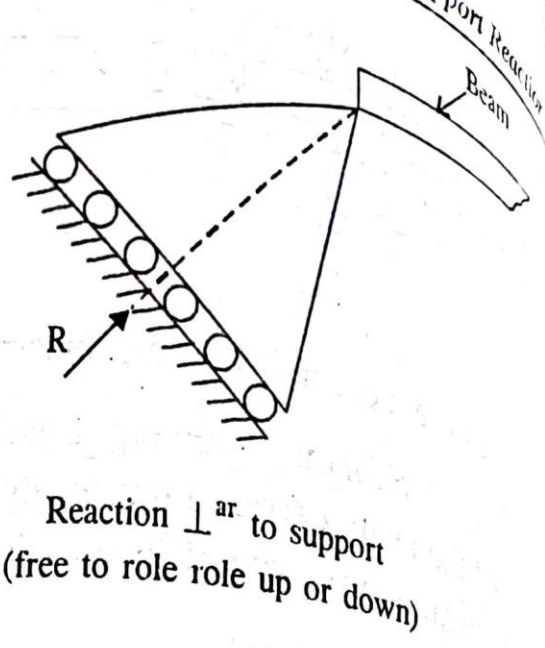


Fig. 9.10.

3) **Hinged Support or Pin-jointed Support :** If the beam is supported on hinge or pin then such support is called a Hinged or Pinned support. In hinged support the beam cannot move in any direction. In hinged beam the reaction may be vertical, horizontal or inclined depending upon the type of loading.

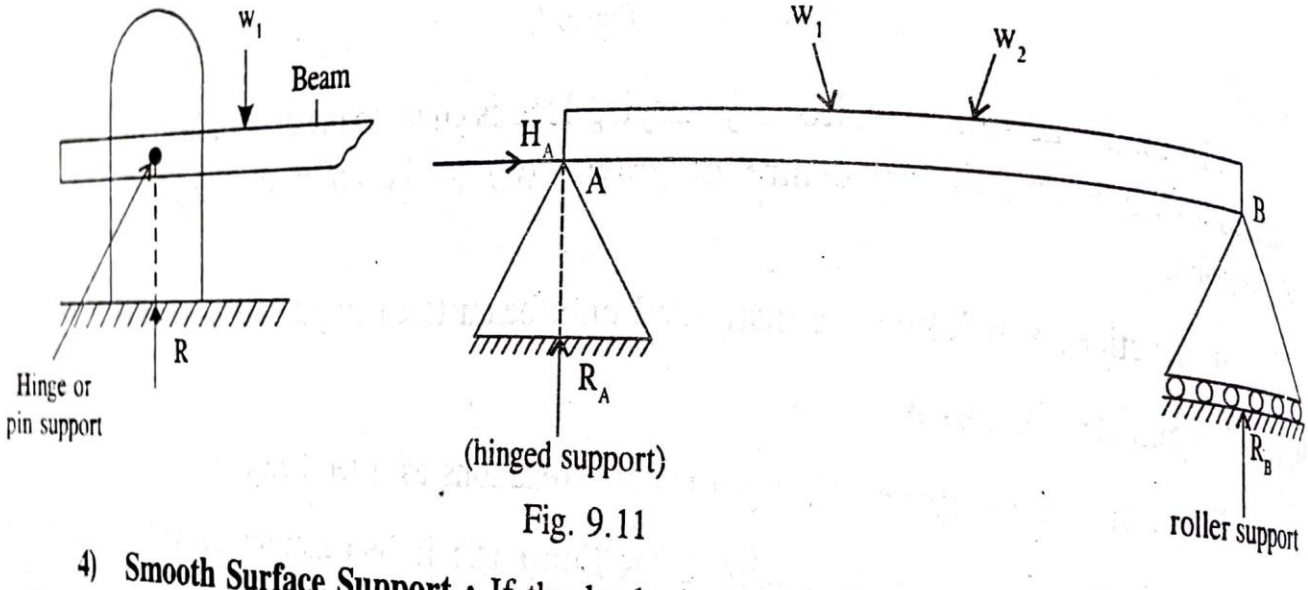


Fig. 9.11

4) **Smooth Surface Support :** If the body is supported or in contact with a smooth surface, then such a support is called a smooth surface support. In such cases, the reaction is ⊥ar to the support. In cases of spheres the reaction acts ⊥ar to support surface and passes through the centre of sphere C as shown in fig. 9.12.

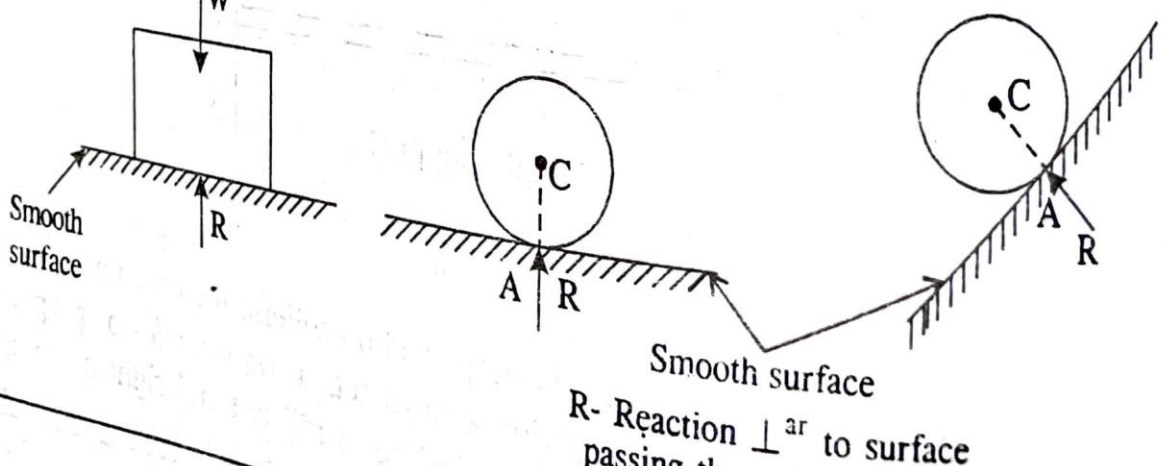


Fig.9.12

5) Fixed or Built-in or Encastered Support : If the end of the beam is fixed or Built-in, then such a support is called as *fixed support*. In fixed support the reaction may be vertical, horizontal or inclined and in addition there will be a *moment* acting at fixed end as shown in fig. 9.13.

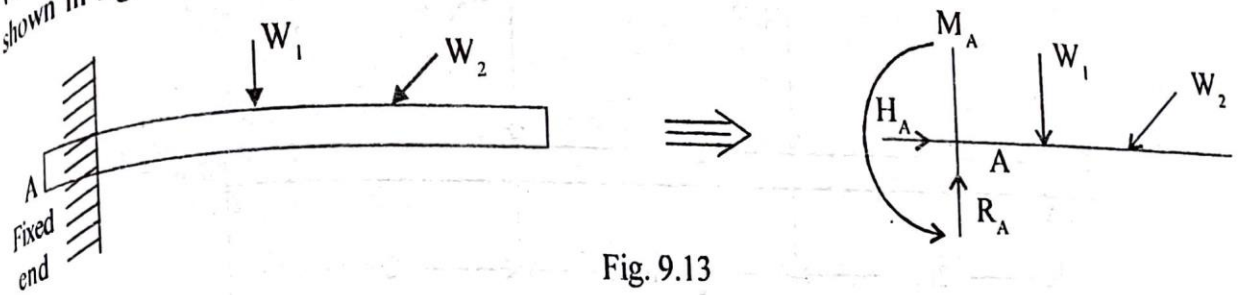


Fig. 9.13

9.5 Free Body Diagram (FBD)

The diagrammatic representation of the body which is isolated or separated from the contact surfaces and the contact surfaces are replaced by support reaction is called Free Body Diagram (FBD). The F.B.D. is in equilibrium. Some of the FBD are shown in fig. 9.14.

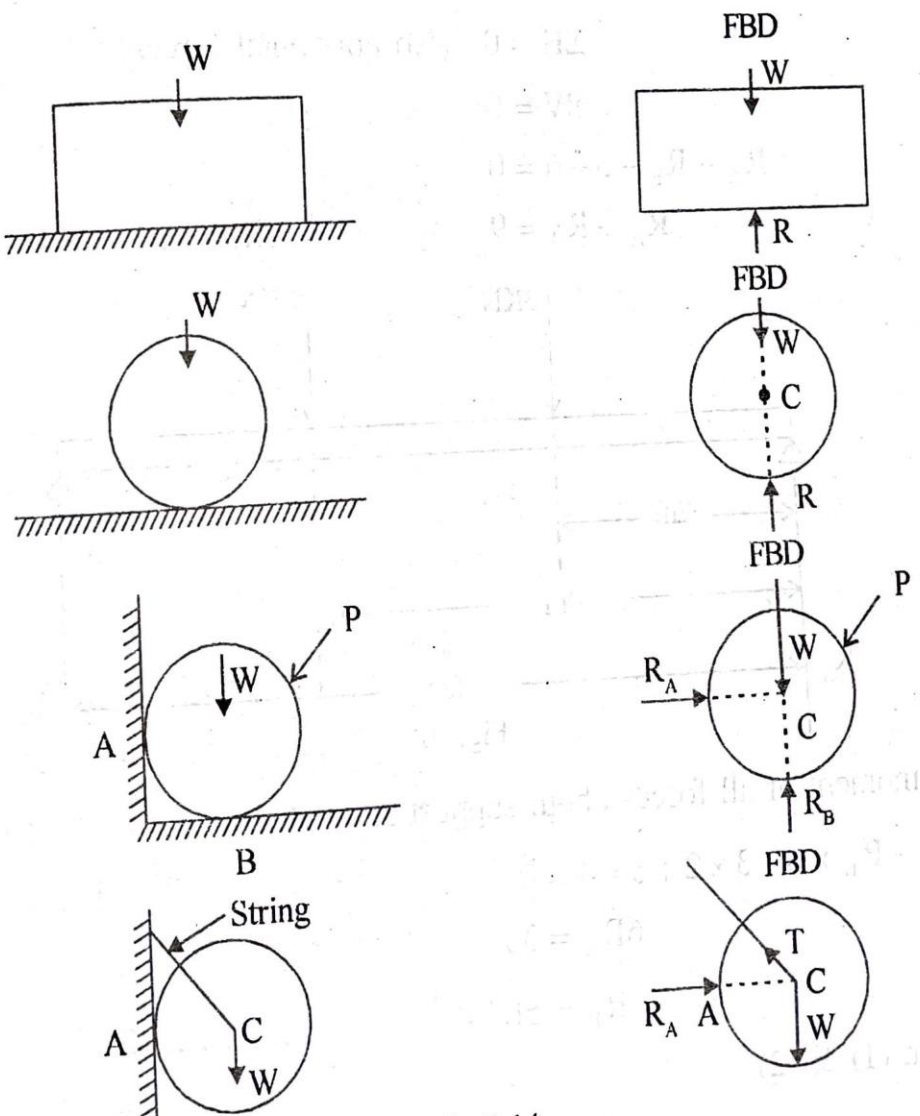


Fig. 9.14

Sign Conversion : Loads acting upwards direction and towards rightside are *positive* and loads acting downwards and leftside are *negative*.