# Lecture 7,8,9,10:

Plastic, Rubber, FRP, Ferrocement,

## PLASTIC

- The most common definition for plastics is that they are natural or synthetic resins, or their compounds, which can be moulded, extruded, cast or used as films or coatings.

- Most plastics are of organic nature composed of compounds of carbon and other elements like hydrogen, oxygen carbon and nitrogen

- The development of plastic may broadly be grouped into three stages: Parkesite by a Scottish Alexander Parkes (1985), Bakelite by a Belgian scientist L Bakeland(1909); and the third stage of plastic revolution started by an Austrian scientist Pollak (1924). After the 2nd World war, plastic has proved to be very important engineering material.

Composition: The plastic is an inorganic substance consisting of natural or synthetic binders or resins with or without moulding compounds. Moulding compounds like fillers, plasticizers, solvents, pigments added in order to give desired properties to finished plastic articles.

**Manufacture**: All plastics are manufactured by the chemical reaction known as 'polymerization' In polymerization large number of simple molecules of organic substances called monomers are combined or synthetised or linked together, to form polymers, by the following methods

- Addition polymerization: in this method, large number of simple molecules are chemically added together to increase the average molecule size without wastage. Such polymerization takes place by three steps namely, (i) initiation (ii) chain propagation and (iii) termination. The polymers obtained by this method are polyethylene, polypropylene, pvc, polystyrene etc.

- Condensation polymerization: is the process of linking together of unlike monomers accompanied by splitting off a small molecule. The process is slow and requires a catalyst. Polymers obtained by this method are phenol-formaldehyde (commonly known as bakelite), carbamide, etc.

- Copolymerisation: It is the addition polymerization of two or more chemically different monomers. This method has been extensively applied, in the artificial rubbers.

**Classification of Plastics**: Most commonly, plastics are classified into,

- Thermoplastic: those which soften on the application of heat, with or without pressure and require cooling to be set to a shape. These are essentially long chain macro-molecule with a limited number of cross links. Important thermoplastic materials are,

  - Polythenes: They are wax like in appearance, transluscent, odourless, flexible, chemically resistant and do not absorb moisture. They have high resistivity and dielectric strength and are relatively low in cost. They are used in high voltage applications, packaging, moisture proofing and insulation of submarine cables and radar lines.

- Polyvinyl chloride: They are formed from hydrochloric acid, limestone, natural gas and coal. The flexible types are strong, tear resistant and have good aging properties. The rigid types have good dimensional stability and are resistant to water, acid or alkalies. They are used in cable jackets, lead-wire insulation, rubber substitute and fabric coating.

- There are other thermoplastics like silicones, polystyrene, bitumen plastic etc.

- Thermosetting: those plastics which require heat and pressure to be moulded into shape. The thermosetting plastics are characterized by strong cross links between the chains. The important thermosetting materials are,

  - Aminos
    - Urea formaldehyde resin: from the reaction of urea and formaldehyde or its polymers. These cannot offer resistance to heat and are used for high voltage application, for making ball point pen barrels, cosmetic cases etc.
    - Melamines: derived from the reaction of dicyandiamide with formaldehyde. These are resistant to chemicals, water and electric arc. They are extensively used in electric field, treating paper and cloth and for table wares.

  - Phenolics: made from the reaction of phenol and formaldehyde. They are most widely used and cheapest thermosetting plastic, strong, rigid, dimensionally stable, heat and solvent resistant and non-conductor of electricity. They are used into television and radio cabinets, telephones, appliance handles, electrical sockets etc.

  - Epoxy resins: basically a polymer of epichlorohydrin and bisphenol. They are transparent, light, little shrinkage, superior toughness, elasticity and chemical resistance. They are used as insulating material in cable-end boxes, instrument transformers etc.

**\Properties of Plastic:**

Each plastic material has its own peculiar properties to suit its particular use as discussed above. The properties common to most plastics are,

- Light weight
- A wide range of colours
- In many cases non-inflammable, self extinguishing and burn very slowly
- Low electrical conductivity
- Good sound absorption properties
- Bad conductor of heat
- Can be easily fixed in position
- Lack ductility
- Excellent insulating property
- Can be conveniently recycled
- Low thermal conductivity
- Resistance to deterioration by water
- Good resistant to attack by inorganic acid base and salts
- Transparent, transluscent or opaque
- Good dimensional stability
- Good tensile strength
- Good resistance to peeling
- Quite durable
- Easy maintenance
- Provides uniformity in surface finish

**Shortcoming of Plastics**: Following are the shortcoming/limitations of plastic,

- Low heat resistance
- Disintegrate gradually with time
- High coefficient of thermal expansion
- Not very hard
- Exhibit high creep

**Uses of Plastic**: The typical uses of plastics in building are,

- Bath, sink units and sanitary fittings
- Decorative laminates and mouldings
- Electrical conduits
- Floor tiles
- Foams for thermal insulation
- Overhead water tanks
- Paints and varnishes
- Safety glass
- Wall tiles
- Cistern ball floats
- Corrugated and plain sheets
- Electrical insulators
- Films for water, damp proofing
- Joint less flooring
- Lighting fixtures
- Pipes to carry cold water
- Roof lights
- Water resistant adhesives

**Use of PVCs in Buildings:**

The polyvinyl chloride is the most versatile plastic and its use in buildings is becoming popular day by day. It is possible to substantially change or modify the properties of PVC resin by the technique of compounding i.e. addition of other additives to PVC. The advantage of using PVC doors and windows are,

- They are totally rust proof, rot proof, termite proof and water proof
- They are unaffected by coastal saline air, dry heat, sub-zero temp. or tropical rains
- They do not fade, corrode, flake or warp and require almost no maintenance
- They provide and alternative to wood
- They provide better thermal insulation and ideal for air conditioned and heated rooms
- They restrict dust penetration and ideal for operation theatres, computer rooms, food processing plants, electronic factories, pharmaceutical plants etc.

Disadvantages: There are some disadvantages, common to all plastic materials, which are,

- They are not very hard
- They disintegrate gradually with the passage of time
- They exhibit high creep
- They have high coefficient of thermal expansion

**Commercial Forms of Plastic**: Important commercial forms for civil engineering purposes are,

- Plastic Sheets
  - PVC sheet
  - Fabric-backed sheets
  - Polythene sheets
  - Corrugated plastic sheet
- Plastic tiles
  - PVC tiles – used for flooring
  - Fabric backed PVC tiles – used for paving floor in dry conditions
  - Thermoplastic vinyl tiles – suitable for heavy foot traffic in both dry and wet
  - Polystyrene wall tiles – suitable for lining walls of high class buildings

- Plastic laminates: formed by impregnating sheets of fibrous materials such as paper, linen, canvas or silk with a synthetic resin and then compressing the sheets together with the application of heat. The laminated plastics are used for electric insulation, silent gears, pump parts, press tools, decorative purposes in wall paneling etc. Some of the important types are,
    - Laminate bakelite
    - Melamine surfaced phenolic paper laminates
    - Polyster paper laminate
    - Corrugated phenolic-resin bonded paper laminates

- Plastic panels – used for light weight partitions

- Plastic pipes
    - PVC pipes – have good ductility, do not burst due to freezing of water, used for distribution of water, mine drainage, gas distribution etc.
    - Polythene plastic pipes – have inherent flexibility and excellent resistance to breakage, used for water supplies, in chemical and food industries

## RUBBER

Rubber is an important engineering material used in a wide variety of products ranging from tyres of heavy goods vehicles and motor cars to chewing gums. It is an elastomer in which the arrangements of the polymer molecules allows considerable reversible extension to take place at normal temperatures. Columbus discovered rubber, the name given by an Englishman, and the commercial use started with the discovery of 'vulcanization' by Charles Good Year in 1836. Two types of rubber are,\

- Natural Rubber
- Artificial Rubber

Natural Rubber: It is a polymer derived from the sap or latex of the rubber tree, Hevea Brasiliensis. The process of obtaining natural rubber is carried out in the stages of,

- Plantation
- Taping latex
- Purification, and
- coagulation

**Vulcanization of Rubber:**

Vulcanization is the process in which plasticity of the rubber compound is reduced without affecting its elasticity. It is done by adding 1-3 % of sulphur and heating in a closed mould under pressure. So, after vulcanization the material becomes thermosetting where sulphur produces cross linking between the polyisoprene molecules. The effects of vulcanization are,

- increase in tensile strength
- increase in resistance to weathering
- more elastic
- good flexibility
- improved resistance to solvents, and
- good dimensional stability for longer period

**Compounding of Rubber:**

To give desired properties to the rubber, certain compounds are added to rubber. The usual compounds which are used for natural and synthetic rubber are,

- Accelerators
- Anti-oxidants
- Hardeners
- Plasticizers
- Accelerator activators
- Fillers
- Pigments
- Vulcanizing agents

**Synthetic Rubber:**

In the absence of natural rubber, synthetic rubber was first manufactured in America in 1941 which was known as GR-S, a copolymer of styrene and butadiene. Currently production of synthetic rubber exceeds that of natural rubber. Synthetic rubber possesses certain properties which are impossible with the natural rubber. These properties are (i) resistance to acid, grease, kerosene and petroleum, (ii) highly resistant to sunlight, heat and deterioration by oils etc. The different types of synthetic rubbers are,

- SBR polymers
- Neoprene
- Polysulphide elastomers
- Urethane polymers
- Nitrile rubber
- Butyl rubber
- Silicon rubber, and

**Properties of Rubber**: The important properties of rubber are as follows:

- It can absorb shocks due to impact
- It can contain liquids and gases
- It creeps or extends or undergoes slow deformation in length under applied load
- It is a bad conductor of heat
- It is plastic in nature and can be moulded to the desired shapes
- It is possible to change properties by vulcanization and compounding
- It possesses flexibility, resists abrasion and reasonably elastic
- Natural rubber deteriorates in contact with oils, organic liquids etc.
- Synthetic rubber offers great resistance to acids, petroleum products etc.

**Uses of Rubber**: The following are some of the uses of rubbers,

- Thermal insulation
- Rain water and flexible tubing
- Tyres and tubes
- Hose pipes, printing rollers etc.
- As a buffer
- Lining for reservoir
- Belting of all types
- Adhesive
- Mounting material
- Gasketing material

**Forms of Rubber**: The important forms of rubber are,

- Gutta percha rubber: natural, absorbs less water, used for ropes of submarine, as an insulating material in electric works
- Foam rubber: widely used for packing pads, pillows etc.
- Sponge rubber: prepared by adding sodium bicarbonate during vulcanization. It is used as a heat and sound insulating material

- Guayle rubber: natural, from branches of guayule, available in north America
- Smoked rubber: crude rubber, drying is carried out in a smoke room
- Polybutadiene rubber: synthetic rubber, high abrasive resistance and strength, nicely used in producing beltings, floor tiles, automotive moulded goods, hoses, tyres, seals, gaskets etc.

**FRP Composites:**

A Fibre Reinforced Polymer (FRP) composite is defined as a polymer (plastic) matrix, either thermoset or thermoplastic, that is reinforced (combined) with a fibre or other reinforcing material with a sufficient aspect ratio (length to thickness) to provide a discernable reinforcing function in one or more directions.

FRP composites are different from traditional construction materials such as steel or aluminum. FRP composites are anisotropic (properties apparent in the direction of the applied load) whereas steel or aluminum is isotropic (uniform properties in all directions, independent of applied load). Therefore FRP composite properties are directional, meaning that the best mechanical properties are in the direction of the fibre placement.

**Composition of FRP:** Composites are composed of,

- Resin: The primary functions of the resin are to
    - transfer stress between the reinforcing fibres,
    - act as a glue to hold the fibres together, and
    - protect the fibres from mechanical and environmental damage

The most common resins used in the production of FRP grating are 'polysters' (including orthophthalic – "ortho" and isophthalic – "iso"), vinyl esters and phenolics.

- Reinforcements: The primary function of fibres or reinforcements is to carry loads along the length of the fibre to provide strength and stiffness in one direction. Reinforcements can be oriented to provide tailored properties in the direction of the loads imparted on the end product. The largest volume reinforcement is glass fibre.

- Fillers: Fillers are used to improve performance and reduce the cost of a composite by lowering compound cost of the significantly more expensive resin and imparting benefits as shrinkage control, surface smoothness, and crack resistance.

- Additives: Additives and modifier ingredients expand the usefulness of polymers, enhance their processability or extend product durability

Each of these above constituent materials or ingredients play an important role in the processing and final performance of the end product.

**Manufacturing of FRP**:

There are a wide variety of processes available to the composites manufacturer to produce cost efficient products. The principal methods of manufacture are,

- Pultrusion: It is a continuous process of manufacturing composites that have a cross sectional shape. The process consists of pulling a fiber – reinforcing material through a resin impregnation bath and through a shaping die. The dimensions and shape of the die

will define the finished part being fabricated. Inside the metal die, heat is transferred to the reinforcements and liquid resin. The solid laminate emerges from the pultrusion die to the exact shape of the die cavity. The laminate solidifies when cooled and it is continuously pulled through the pultrusion machine and cut to the desired length. The process is driven by a system of caterpillar or tandem pullers located between the die exit and the cut-off mechanism.

- Moulding process: Liquid resin and continuous fiberglass roving are systematically laid in the mould, layer after layer manually, to produce the desired thickness and panel dimensions. The finished moulds are set aside for a predetermined time to allow the panel to cure. The panel is then ejected from the mould. The moulds are cleaned and prepared for the process to begin again.

**Properties of FRP**: The properties which have made the FRP the most commercially successful composite material of construction are,

- Aesthetic appeal: due to superb finish
- Dimensional stability: holds shape
- Easy to repair
- Energy saving: less energy for produc.
- Light transmission: transmits light
- Low maintenance
- Corrosion resistance: excellent
- Durability: has long workable life
- Effect on health: safest material
- Freedom of design: excellent
- Light weight: reduces dead load
- Low investment in tooling

**Applications in Building Industry**: The FRP is an ideal material for building industry as seen from its various applications which may be listed as follows:

- Concrete shuttering: moulds and forms of FRP give the cast concrete shapes of very high quality

- Domes: the domes in enchanting shapes and unique designs and wide dimensions can be created for eye catching aesthetics.

- Door and window frames: the lightweight flush doors and factory made standard window frames of FRP can be suggested for housing due to their long life, easy maintenance and overall reduction in cost

- Internal partitions and wall paneling: flat, corrugated or fancy FRP sheets can be used

- Roof sheets: translucent FRP sheet can be used for versatile medium of lighting

- Structural sections: the available cross section profiles in steel, aluminum or PVC can also be made in FRP with advantage of equal strength at low strength.

- Temporary shelters: The FRP modular systems are ideally suited for temporary shelters at project sites, watchman cabins, green houses, defense shelters, vehicle parking sheds.

- Water storage tanks: the FRP water storage tanks are found to be superior to steel, concrete or galvanized iron tanks.

- Miscellaneous: The properties of FRP are multiple and the applications are limitless .the FRP furniture can be used for auditorium, hotels, restaurants, gardens, parks, lounges, theatres, waiting rooms etc.

## FERROCEMENT:

The term ferrocement is most commonly applied to a mixture of Portland cement and sand reinforced with layers of woven or expanded steel mesh and closely spaced small-diameter steel rods rebar. The material was first introduced by its inventor, Joseph Monier of France in late Eighteen fifties.

Ferrocement can be used to form relatively thin, compound curved sheets to make hulls of boats, shell roofs, water tanks etc. It has been used in a wide range of other applications including sculpture and prefabricated building components.

Ferrocement or more precisely ferro concrete has relatively good strength and resistance to impact. When used in house construction in developing countries, it can provide better resistance to fire, earthquake, and corrosion than traditional materials, such as wood, adobe, and stone masonry. It has been popular in developed countries for yacht building because the technique can be learned relatively quickly, allowing people to cut costs by supplying their own labor. Novelty architecture like 'dinosaurs in the desert', 'giant pair of cowboy boots and hat' were constructed in USA using ferro concrete.

**Construction:**

The desired shape may be built from a multi-layered construction of mesh, supported by an armature, or grid, built with rebar and tied with wire. For optimum performance, steel should be rust treated, (galvanized) or stainless steel. Over this finished framework, an appropriate mixture (grout or mortar) of Portland cement, sand and water and/or admixture is applied to penetrate the mesh. During hardening, the assembly may be kept moist, to ensure that the concrete is able to set and harden slowly and to avoid developing cracks that can weaken the system. Steps should be taken to avoid trapped air in the internal structure during the wet stage of construction. Modern practice often includes spraying the mixture at pressure, (a technique called shotcrete), or some other method of driving out trapped air.

**Advantages**: The advantages of a well built ferro concrete construction are,

¤ low weight, ¤ low maintenance cost, ¤ and long life

**Disadvantages**: There are some disadvantage which are,

- Labor intensive and makes expensive for developed countries
- If not properly constructed, air voids can turn to pools of water, steel will rust and expand, causing the system to fail