MODERN CONSTRUCTION MATERIALS

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COURSE OBJECTIVES:

- To study and understand the properties of modern construction materials used in construction such as special concretes, metals, composites, water proofing compounds, non weathering materials, and smart materials.

SPECIAL CONCRETES

Concretes, Behaviour of concretes – Properties and Advantages of High Strength and High Performance Concrete – Properties and Applications of Fibre Reinforced Concrete, Self compacting concrete, Alternate Materials to concrete on high performance & high Strength concrete.

METALS

Types of Steels – Manufacturing process of steel – Advantages of new alloy steels – Properties and advantages of aluminium and its products – Types of Coatings & Coatings toreinforcement – Applications of Coatings.

COMPOSITES

Types of Plastics – Properties & Manufacturing process – Advantages of Reinforcedpolymers – Types of FRP – FRP on different structural elements – Applications of FRP- Cellular Cores – Geo-synthetics-. Polymers - Fibre reinforced plastic in sandwich panels – Adhesives and sealants. Structural elastomeric bearings, Moisture barriers Applications in civil engineering.

OTHER MATERIALS

Thermal insulation and acoustic absorption materials- Recycled materials- Water Proofing Compounds – Non-weathering Materials – Flooring Materials – surface preparation materials.

SMART AND INTELLIGENT MATERIALS

Types & Differences between Smart and Intelligent Materials – Special features – Casestudies showing the applications of smart & Intelligent Materials.

WHAT IS CONCRETE?

- Construction material
- Mixture of portland cement, water, aggregates, and in some cases, admixtures.
- The cement and water form a paste that hardens and bonds the aggregates together.
- Often looked upon as “man made rock”.
- Versatile construction material, adaptable to a wide variety of agricultural and residential uses.
- Strong, durable, versatile, and economical. Can be placed or molded into virtually any shape and reproduce any surface texture.
- The most widely used construction material in the world.
- In the United States almost twice as much concrete is used as all other construction materials combined.
- The ready-mix concrete producer has made concrete an appropriate construction material for many applications.

- **WATER**
  - Good water is essential for quality concrete.
  - Should be good enough to drink--free of trash, organic matter and excessive chemicals and/or minerals.
  - The strength and other properties of concrete are highly dependent on the amount of water and the water-cement ratio.

- **AGGREGATES**
  - Aggregates occupy 60 to 80 percent of the volume of concrete.
  - Sand, gravel and crushed stone are the primary aggregates used.
  - All aggregates must be essentially free of silt and/or organic matter.

- **CHEMİCAL ADMİXTURES**
  - Materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes.
  - In normal use, admixture dosages are less than 5% by mass of cement, and are added to the concrete at the time of batching/mixing.
  - The most common types of admixtures are:
    - Accelerators
    - Acrylic retarders
    - Air Entraining agents
    - Water-reducing admixtures
- **REINFORCEMENT**
  - Strong in compression, as the aggregate efficiently carries the compression load.Weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail.
  - Reinforced concrete solves these problems by adding either metal reinforcing bars, steel fibers, glass fiber, or plastic fiber to carry tensile loads.

- **CEMENT**
  - Crystalline compound of calcium silicates and other calcium compounds having hydraulic properties.
  - Considered hydraulic because of their ability to set and harden under or with excess water through the hydration of the cement’s chemical compounds or minerals.
  - **Uses -** Main use is in the fabrication of concrete and mortars
  - **Modern uses**

    -Building (floors, beams, columns, roofing, piles, bricks, mortar, panels, plaster)

    -Transport (roads, pathways, crossings, bridges, viaducts, tunnels, parking, etc.)

    -Water (pipes, drains, canals, dams, tanks, pools, etc.)

    -Civil (piers, docks, retaining walls, silos, warehousing, poles, pylons, fencing)

    -Agriculture (buildings, processing, housing, irrigation)

Admixtures in concrete (IS:9103-1999)

- Admixtures are the materials other than the three basic ingredients of cement concrete— cement, aggregate and water—added to the concrete mix before or during mixing to improve certain of its properties in fresh or hardened state.
- The properties commonly modified are rate of hydration or setting time, workability, dispersion and air entrainment.

Functions of admixtures

- To accelerate the initial set of concrete, i.e., to speed up the rate of development of strength at early ages,
- To retard the initial set,
- To increase the strength of concrete,
- To improve workability,
- To reduce heat of evolution,
- To increase durability of concrete—resistance to freezing and thawing,

Classification of admixtures
Accelerators:

- Accelerators reduce the setting time, accelerate the rate of hydration of cement and consequently the rate of gain of strength.
- The examples of accelerators are sulphates with an exception of calcium sulphate, alkali carbonates aluminates and silicates, aluminium chloride, calcium chloride, sodium chloride, sodium and potassium hydroxides, calcium formate, formaldehyde, para formaldehyde, etc.
- Some substances may act as accelerators or as retarders according to the proportion added.
- For example, $CaCl_2$ when added up to 2 per cent by weight of cement acts as accelerator, but on increasing the proportion, it acts as retarder and leads to flash set.

Retarders:

- Retarders increase the setting time and thus delay the setting of cement. Since these reduce the rate of hydration, more water is available and better is the workability.
- Retarders increase the compressive strength under freezing and thawing.
- Calcium sulphate, sugar, starch, cellulose, ammonium, ferrous and ferric chlorides, sodium hexametaphosphate, lignosulphonic acid and their salts, carbohydrates, hydrocarboxylic acids and their salts are a few examples of retarders.

Water proofers:

- Cement mortar or concrete should be impervious to water under pressure and also should have sufficient resistance to absorption of water.
- The concrete can be made water resistant with the additives which may be water repellent type or pore filling type. But, the ultimate aim is to produce concrete impervious to water.
- The examples of water repellent materials such as soda and potash soaps are chemically active, whereas calcium soaps, resin, vegetable oil, fats, waxes and coal tar residue are the examples of chemically inactive materials.
- The examples of pore filling materials are alkaline silicates and notably silicate of soda, aluminium and zinc sulphate and aluminium and calcium chlorides.

Finely divided workability agents :

- It increase the workability by increasing the amount of paste in concrete and hence the cohesiveness. However, if used in excess, the quantity of water has to be increased which causes cracking and loss of strength.
- Lime, bentonite, kaolin, chalk, diatomaceous earth are a few examples of workability agents.

Bleeding agents :

- To check bleeding, paraffin wax at about. 0.2–0.75 per cent by mass of cement or air entrainment is used. The latter is more effective but requires high degree of control.

Colouring agents :

- Colouring agents used in concrete work are mainly raw umber (brown), ferrous oxide (black), red oxide (red), and chromium oxide (green).

Air entrained agents :

- The air intentionally introduced in the cement during its manufacture or during making concrete is known as entrained air.
- It is different from entrapped air where the continuous channels are formed, thus increasing the permeability.
- In the case of entrained air, the voids formed are discontinuous and are less than 0.05 mm in diameter.
- Air entrainment increases workability, and resistance of concrete to weathering.

Air entrained agents :

- The possibility of bleeding, segregation and laitance is also reduced. However, there is some loss in the strength of concrete.
- The air content should be from 4 to 7%, by volume, according to the maximum size of aggregate used.
- The air entrainment may be done by surface active agents, chemicals, or by cement dispersing agents.

Surface active agents:

- It reduce the surface tension and are commonly known as air entraining agents.
- An addition of 5 percent of air may increase the compacting factor by 0.07 and a corresponding increase of slump: 12 to 50 mm.
- Following are some of the examples of air entraining agents:
  - Natural wood resins and their soaps, of which vinsol resin is the best.
  - Animal or vegetable fats and oils such as tallow or olive oil and their fatty acids such as stearic acid and oleic acids and their soaps.
  - Wetting agents such as alkali salts of sulphonated or sulphated organic compounds. A well known trade material is Darex. Other trade names of this category are N. Tair, Airalon, Orvus, Teepol, Petrosan and Cheecol.

Chemicals :

- The addition of chemicals such as zinc or aluminium powder releases gases. This method is generally not adopted since it requires high control.

Dispersing agents :

- They are surface active chemicals imparting electrostatic charges on the cement particles. This causes cement particles to repel each other and thus prevent coagulation.
- A small amount of air is also entrained in the concrete and workability is increased.
- The dispersing agents reduce the strength.
- The most commonly used dispersing agent is calcium lignosulphonate.

Plasticizer

- Plasticizers are organic or a combination of organic and inorganic substances, which allow a water reduction for a given workability, or give higher workability at the same water content.
- Plasticizers are principally surface active (surfactants). They induce a negative charge on the individual cement particles such that the fine cement particles are dispersed due to inter particle repulsion.
- Fine cement particles being very small clump together and flocculate when water is added to concrete.

Puzzolana

- Puzzolanas are siliceous materials which are themselves inactive but react, in the presence of water, with lime to form compounds having cementitious properties.
- The examples of puzzolana are lime, fly ash, burnt clay and blast furnace slag.
- Puzzolanas react with free lime in cement and improve the durability of concrete, and reduce the rate of hardening of concrete, which is the principal objection to its use
- Puzzolanas are classified as natural and artificial.

- **Expansion producing admixtures** are used to counteract the drying shrinkage of concrete. Granulated iron and chemicals are most effective.
- **Bonding mixtures** are used to join the old and the new concrete surfaces or between the successive concrete lifts. The examples are synthetic latex emulsions—made from natural rubber, synthetic rubber, polyvinyl chloride.
- **Fungicides**: The examples are arsenic, tin, mercury compounds, Tributyl tin acetate.
- **Algicides :** The examples are sodium pentachlorophenate. The usual dosage is 0.2 per cent by weight of cement.

High performance concrete

- High performance concrete is defined as concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing, and curing practices.
- The requirements may involve enhancements of characteristics such as placement and compaction without segregation, longterm mechanical properties, high early-age strength, toughness, volume stability, durability service life (greater than 75 years) in severe environments, flow ability and self-leveling capability, or low heat of hydration.
- Often a higher modulus of elasticity, not compressive strength, is the controlling requirement in HPC construction.
- A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete.

High performance concrete

- A high-strength concrete has a specified compressive strength for design of 40 MPa or greater.
- The specification of high-strength concrete generally results in a true performance specification in which the performance is specified for the intended application, and the performance can be measured using a well accepted standard test procedure.
- The same is not always true for a concrete whose primary requirement is durability.
- Durable concrete specifying a high-strength concrete does not ensure that a durable concrete will be achieved.
- In addition to requiring a minimum strength, concrete that needs to be durable must have other characteristics specified to ensure durability.
- In the past, durable concrete was obtained by specifying air content, minimum cement content and maximum water-cement ratio.

High performance concrete -material

- Most high-performance concretes produced today contain materials in addition to Portland cement to help achieve the compressive strength or durability performance.
- These materials include fly ash, silica fume and ground-granulated blast furnace slag used separately or in combination.
- These cementitious materials can exceed 25% of the total cement by weight.
- Typical HPC today can include 5% to 15% silica fume, 50% to 65% slag cement (as much as 80% in mass concrete), and up to 50% fly ash. Silica fume contributes to strength and durability; fly ash and slag cement result in better finishability, decreased permeability, and increased resistance to chemical attack.
- HPC mixtures are often proportioned to achieve low permeability. Lower concrete permeability provides corrosion resistance for reinforcing steel by reducing the rate of chloride ion migration into the concrete.

High performance concrete -material

- Slag cement improves the workability, placeability, and consolidation of concrete, resulting in better finishing.
- Coarse aggregates in HPC occupy 35–70% of the volume of concrete, their properties influence the properties of hardened concrete significantly.
- Usually an aggregate with specific gravity more than 2.55 and water absorption less than 1.5% (except for light weight aggregates) is desirable.
- Chemical admixtures such as high-range water-reducers are needed to ensure that the concrete is easy to transport, place and finish. Retarding admixtures are used to check the early setting problems.
- For high-strength concretes, a combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength. Typically, high-range water-reducing admixtures are used.

High performance concrete -material

- Concrete for bridge decks typically include water-reducing admixtures. Natural wood resins and sulphonated compounds are used for air entrainment.
- Most high-performance concretes have a high cement content and a water-cement material ratio of 0.40 or less. However, the proportions of the individual constituents vary depending on local preferences and local materials.
- Mix proportions developed in one part of the country do not necessarily work in a different location. Many trial batches are usually necessary before a successful mix is developed.
- High-performance concretes are also more sensitive to changes in constituent material properties than conventional concretes. Because many characteristics of high-performance concrete are interrelated, a change in one usually results in changes in one or more of the other characteristics.

High strength concrete

- For mix made with normal weight aggregates, high strength concrete (HSC) is considered to be the one having a compressive strength in excess of 40 MPa.
- To produce concrete above this strength more stringent quality control and more care in selection and proportioning of materials are needed.
- The tricalcium aluminate component is kept as low as possible (<8%).
- Most cements used to produce HSC have fineness in the range of 300–400 m2/kg with an exception of high early strength cement for which fineness should be at least 450 m2/kg.
- For HSC a smaller maximum size of coarse aggregate leads to higher strength. Fine aggregate should have a F.M >3.

High strength concrete - characteristics

- Workability :
  - In the early stages of its development, the HSC has a tendency to be sticky and stiff due to large amounts of fines (high cement content, and pozzolana), a low water-cement ratio, and a normal water-reducing admixture.
  - However, with the advent of superplasticizers it is possible to have a desired high workability without causing segregation even at a lower w/c ratio of 0.3.
- Strength:
  - The most noteworthy point about HSCs is their capacity to develop strength at a rapid rate without steam curing.
  - Concrete can develop 20 to 27 MPa on normal curing within 24 hours and the ultra HSC can develop 42 MPa in 12 hours and 64 MPa in 24 hours.

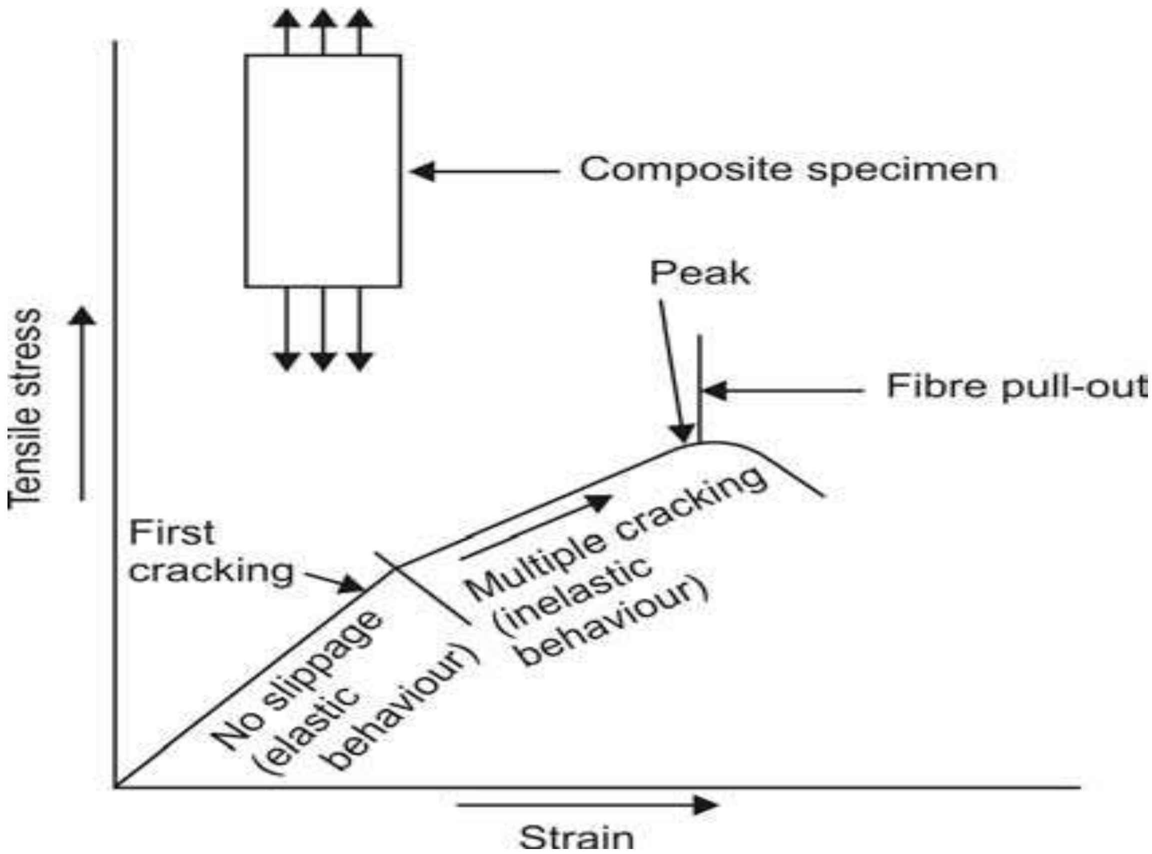
High strength concrete - characteristics

- Microstructure, stress-strain relation, creep and fracture:
  - As a result of reduction in the size and number of micro cracks in HSCs, its stress-strain relation, creep and fracture behaviour is different from the normal concretes.
  - HSCs, having compressive strengths in the range of 30 to 75 MPa behave more like a homogeneous material as compared to PCC.
  - For HSCs the stress strain curves are steeper and more linear to a higher stress-strength ratio than in normal strength concretes, because of a decrease in the amount and extent of micro-cracking in the transition zone.
  - Thus it shows a more brittle mode of fracture and less volumetric dilation.
  - Also the amount of micro-cracking in HSC associated with shrinkage, short term loading, and sustained loading is significantly less.

Fibre reinforced concrete

- Conventional concrete is modified by random dispersal of short discrete fine fibres of asbestos, steel, sisal, glass, carbon, polypropylene, nylon, etc.
- Asbestos cement fibres so far have proved to be commercially successful.
- The improvement in structural performance depends on the strength characteristics, volume, spacing, dispersion and orientation, shape and their aspect ratio (ratio of length to diameter) of fibres.

Fibre reinforced concrete



Behaviour of fibre reinforced concrete

Fibre reinforced concrete

- The tensile cracking strain of cement matrix is about 1/50 of that of yield of steel fibres.
- Consequently when FRC is loaded, the matrix cracks long before the fibres are fractured.
- Once the matrix is cracked the composites continue to carry increasing tensile stress, provided the pullout resistance of fibres at the first crack is greater than the load at the first cracking.
- The bond or the pullout resistance of the fibres depends on the average bond strength between the fibres and the matrix, the number of fibres crossing the crack, the length and diameter of fibres, and the aspect ratio.

Fibre reinforced concrete

- The first flexural cracking load on a FRC member increases due to crack arresting mechanism of the closely spaced fibres.
- After the first crack fibres continue to take load provided the bond is good.
- Thereafter the fibres, reaching the breaking strain fracture.
- The neutral axis of the section shifts and the fibres of adjacent layers fracture on reaching the breaking strain.
- Failure occurs when the concrete in compression reaches the ultimate strain.

Polymer concrete

- The strength of concrete is greatly affected by porosity and attempts to reduce it by vibration, pressure application, spinning, etc. are of little help in reducing the water voids and the inherent porosity of gel which is about 28 per cent.
- The impregnation of monomer and subsequent polymerisation reduces the inherent porosity of the concrete.
- Polymers—polyvinyl acetate, homopolymer emulsions and vinyl acetate copolymer emulsions—are added to increase strength, resistance to oil, grease, and abrasion.
- They also improve bond between new and old concrete and are useful for prefabricated structural elements and prestressed concrete.

Polymer concrete

- The disadvantages are that they are very brittle and expensive.
- For heavy duty Industrial floor the concrete mix used is 1:2:2. Concrete to PVA emulsion in the ratio 3:1 is then prepared. For domestic or office floor cement and sand in the ratio of 1:2 is mixed. The cement mortar: PVA emulsion is then made in the ratio 2:1.
- The available polymer concrete materials are
  - polymer impregnated concrete (PIC),
  - polymer cement concrete (PCC),
  - polymer concrete (PC) and,
  - partially impregnated and surface coated polymer concrete

Polymer concrete

- **Polymer impregnated concrete**
  - It is a conventional concrete, cured and dried in oven.
  - A low viscosity manomer is then diffused and polymerised by using radiation, heat or by chemical initiation.
  - The manomers used are, methylmethacrylate (MMA), styrene, acrylonitrile, t-butyl styrene, etc.
- **Polymer cement concrete**
  - It is made by mixing cement, aggregates, water and manomers, such as polyester-styrene, epoxy styrene, furans, venylidene chloride.
  - The plastic mix is moulded, cured, dried and polymerised.
- **Polymer concrete**
  - In this type of concrete cement is not used and the aggregates are bound with a polymer binder.
  - It is most suitable for structures with a high ratio of live load to dead load and composite construction.

Light weight concrete

- Lightweight aggregate concrete is particularly suitable for use where low density, good thermal insulation or fire protection are required but not all of the available aggregate are equally suitable for any particular application.
- It is best produced by entraining air in the cement concrete and can be obtained by anyone of the following methods:
  1. By making concrete with cement and coarse aggregate only. Sometimes such a concrete is referred to as *no-fines concrete*. Suitable aggregates are—natural aggregate, blast furnace slag, clinker, foamed slag, etc. Since fine aggregates are not used, voids will be created and the concrete produced will be light weight
  2. By replacing coarse aggregate by porous or cellular aggregate.

Light weight concrete

- The concrete produced is known as *cellular concrete* which is further classified as follows:
- **Based on manufacturing method** :

    classified as foam concrete and gas concrete.
- **Based on type of binding material**:

    classified as gas and foam concrete (Portland cement),

    gas and foam concrete (lime and sand),

    gas slag and foam slag concretes (lime and finely divided blast furnance slag or fly ash).

Light weight concrete

- **Foam concrete** is obtained by mixing cement paste or mortar with stabilized foam.
- After hardening, the foam cells form concrete of a cellular structure.
- The foam is obtained by stirring a mixture of resin soap and animal glue.
- The best foaming agents are alumino sulpho napthene compounds and hydrolysed slaughter blood.
- This concrete is very suitable for heat insulation purposes.
- The following are the type of foam concrete
  - Heat insulating foam concrete
  - Structural and heat insulating foam concrete
  - Structural foam concrete

Light weight concrete

- **Gas concrete** is manufactured by expanding the binding material paste, which may or may not include aggregates. It is also known as *aerated* concrete.
- The mix is expanded by gas forming substances, but care should be taken to synchronize the end of gas formation with the beginning of mix setting.
- The setting time of cement may be regulated with the aid of accelerators (such as dihydrate gypsum) or retarders (such as industrial sugar, or molasses, introduced in amounts from 0.1 to 2.5 kg/m3).
- The approximate relative proportions of gas concrete ingredients are as follows: 90% Portland cement, 9.75% powdered lime, 0.25% aluminium power (for a water to cement ratio of 0.55– 0.65). About 2/3 of sand are ground in a wet state.

Light weight concrete

Advantages

- The basic economy of LWC can be demonstrated by the savings achieved in associated reinforcement requirement.
- LWC has superior resistance of shear elements to earthquake loading since seismic forces are largely a direct function of deal weight of a structure, is also one among the other advantages of LWC.
- Due to lower handling transportation, the construction cost, the light weight concrete is ideally suited for the production of precast concrete elements and prefabricated elements.

Application

- 1. Low density cellular concrete is used for precast floor and roofing units.
- 2. As lood bearing walls using cellular concrete blocks.
- 3. As insulation cladding to exterior walls of structures

Ready mix concrete

- Ready mixed concrete (RMC) is a concrete, delivered at site or into the purchaser's vehicle, in plastic condition and requires no further treatment before being placed in a position in which it is to set and harden.
- It is a high quality concrete of required grade produced under strictly controlled conditions in a centralised automatic batching plant and supplied to the customer in a transit mixer truck for its placement at site.
- The concrete can be mixed either dry at the batching plant, loaded into agitator truck mixers and water added during transportation; or it can be mixed wet at the batching plant, discharged into the agitator truck mixers and transported to site.
- The first RMC plant was established in the year 1992 in Pune.
- At present, RMC plants are located in almost all the cities of India.

Ready mix concrete

- Use of RMC to its full advantage requires more careful planning on the site as compared to the site mixing.
- Due to better quality control measures adopted, RMC can be considered to be almost a factory-made product, yet it is not.
- It is advantageous not only for mass concreting but also for small quantities of concrete to be placed at intervals.
- RMC is extremely useful on congested sites or in road construction where limited space is available for aggregate stock piling and mixing plant.
- The major set back to the use of RMC is its cost. Though a little bit expensive, the increasing emphasis on quality, with skilled labour becoming expensive, and its inherent advantages out weigh the cost.

Ready mix concrete

- Advantages
  1. Enhanced quality and durability resulting in lower maintenance costs and increased speed of construction.
  2. Ready mix concrete is consistently of the same quality and provides a high quality of construction material; construction time is also reduced.
  3. It reduces congestion at the site and prevents traffic jams.
  4. It hastens infrastructure development and thus provides more employment opportunities.
  5. It is an environmentally safer alternative.

Self-Compacting Concrete(SCC)

- SCC provides improvements in strength, density, durability, volume stability, bond, and abrasion resistance.
- SCC is especially useful in confined zones where vibrating compaction is difficult.
- The reduction in schedule is limited since a large portion of the schedule is still controlled by the time required to erect and remove formwork.
- Although the schedule reduction is limited, it is still sufficient that the reduction in labor costs overcomes the higher material costs.
- Self-compacting concrete may be especially beneficial when used in combination with steel plate reinforced concrete structures, which requires a flowable concrete due to the complicated geometries.
- It is just usage of extra admixtures (super plasticizers and viscosity modifying admixtures) and different amounts of composite materials that makes SSC act different to normal one.

Self-Compacting Concrete(SCC)

- In SSC, high amount of supplementary cementitious materials, up to 70% of the total powder content, are added.
- Normally these supplementary materials are fly ash, silica flume, blast furnace slag etc.
- Since SSC does not require any compaction, it saves time, labour and energy. Also, good surface finish is produced.
- Self-Compacting concrete is characterized by high powder content.
- The parameter that is important in SSC is water-powder ratio, water-cement ratio is completely ignored.
- Other important parameters are fly ash content, sand-aggregate ratio, paste percentage, types of admixture used, etc.
- The aggregate content in SSC is smaller than that for conventional concrete requiring vibration.

Characteristics of SCC

- **Non-Segregating:** The aggregate stay in suspension in the mix as it flows into the form.
- **Non-Bleeding:** Water does not rise to the top of the mix or is observed on the outer edges of a flow test.
- **Vibration:** No vibration is required during placement. SCC flows around rebar and other inclusions in the form under its own weight.
- **Flow spread:** Flow spreads of 45 cm diameter or grater are obtainable.
- **Set time:** The initial set time in many SCC mixes increase upwards of 90 minutes, depending on the admixtures used and water content of the mix.
- **Workability:** Workability of Self-Compacting concrete is equilibrium of its fluidity, deformability and resistance to segregation and filling ability. This equilibrium has to be maintained for a sufficient time period to allow for its transportation, placing and finishing.

Application of SCC

- The main reason for the employment of Self-Compacting concrete are the shortened construction period, assured compaction in the structural elements; especially in confined zones where vibrating compaction is difficult and, to eliminate noise due to vibration; effective especially at products plants.

- Other applications of Self-Compacting concrete are bridge (anchorage, arch, beam, girder, tower, pier, joints between beam and girder); box culvert; building; concrete filled steel column; tunnel (lining, immersed tunnel, fill of tunnel); dam (concrete around structure); concrete products (block, culvert wall, water tank, slab, and segments); diaphragm wall; tank (side wall, joint between side wall and slab).

Metal

- Metals are aiming the most useful building materials.
- They exist in nature as compounds like oxides, carbonates, sulphides and phosphates and are known as ores.
- Metals are derived from ores by removing the impurities.
- Those used for engineering purposes are classified as ferrous metals, with iron as the main constituent, e.g. cast iron, wrought iron and steel and others like aluminium, copper, zinc, lead and tin in which the main constituent is not iron as non ferrous metals.

Steel

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

Types of steel	Carbon content (%)
Dead mild steel	< 0.15
Mild steel	0.15 - 0.3
Medium carbon steel	0.3 - 0.8
High carbon steel Or hard steel	0.8 – 1.5 (>1 is also called as cast steel or tool steel)

Manufacturing methods

- The prominent steel-making processes are:
  - 1. Bessemer process
  - 2. Cementation process
  - 3. Crucible process
  - 4. Open Hearth process
  - 5. Electric Smelting process
  - 6. Duplex process
  - 7. Lintz and Donawitz (L.D.) process

- The most prominent present-day steel-making process is the Bessemer process was introduced in 1856.
- The pig iron is first melted in Cupola furnace and sent to Bessemer converter (Figure) Blast of hot air is given to oxidize the carbon.

Manufacturing methods

- Depending upon the requirement, some carbon and manganese is added to the converter and hot air is blasted once again.
- Then the molten material is poured into moulds to form ingots. L.D. process is modification of the Bessemer process in which there in no control over temperature.
- By this method steel can be made in hardly 25 minutes.
- In Open-hearth process also known as Siemen's-Martin process, the steel produced is more homogeneous than by Bessemer's.
- The electric process is costly but no ash or smoke is produced.
- The Crucible process involves melting of blister steel or bars of wrought iron in fire clay crucibles.
- Cast steel so obtained is very hard and is used for making surgical equipments.
- The Duplex process is a combination of Acid Bessemer process and Basic Open Hearth process.

Alloy steel

- The important reasons for alloy additions are:
  1. To increase the hardenability of steel. The steel in this group are usually heat treated by quenching and tempering, for it is only this way that the added expanse of the alloys can be justified through the better combination of properties that is obtained.
  2. To strengthen the steel when it is to be used without special heat treatment. The steels that fall in this category are designed specifically for constructional purposes.
  3. To confer some special property such as machinability, corrosion resistance wear resistance, etc.

Aluminium

- The principal constituents of bauxite (Al2O32H2O) which yield aluminium on a commercial scale are hydrated oxides of aluminium and iron with some silica.
- Some of the other aluminium ores are corundum, kaolin or china clay, and kryolite.
- The ore is purifed by Bayer's process and is reduced to aluminium by Hall Hiroult's process in two stages.
- In the first stage bauxite is converted into alumina by roasting, grinding, heating (with sodium hydrate) and filtering.
- Then it is agitated for several hours to precipitate the hydrate, which is separated, washed and calcined at 1000° C.
- In the next stage aluminium is extracted by electrolysis of alumina in a molten bath of crystolite (a fluoride of alumina and sodium).

Aluminium

- Aluminium is silver white in colour with a brittle metallic lustre on freshly broken surface.
- It is malleable, less ductile than copper but excels zinc, tin, and lead.
- Aluminium is harder than tin. Aluminium is very light, soft, strong and durable, has low thermal conductivity but is a good conductor of electricity.
- Aluminium can be riveted and welded, but cannot be soldered. It can be tempered at 350° C.
- The melting point is 657° C, tensile strength is 117.2 N/mm2 in the cast form and 241.3 N/mm2 when drawn into wires.
- Aluminium is found to be resistant to the attack of nitric acid, dissolves slowly in concentrated sulphuic acid and is soluble in hydrochloric acid.
- At normal temperature it is not affected by sulphur, carbonic acid, carbonic oxide, vinegar, sea water, etc., but is rapidly corroded by caustic alkalis.

Alloys:

- A material made of two or more metals, or of a metal and another material.
- For example, brass is an **alloy** of copper and zinc; steel is an **alloy** of iron and carbon.
- Some common alloys are
  - Brass is made of 35% zinc and 65% copper and is used for musical instruments, jewellery, faucets, and decorative hardware.
  - Stainless steel is made of 18% chromium, 80.6% iron, 1% nickel and 0.4% carbon and is used for tableware, cookware and surgical tools.
  - Steel is made of 99% iron and 1% carbon and is used for tools, car bodies, machinery, girders and rails.
  - Bronze is made of mostly copper and some tin and is used for boat hardware, screws and grill work.
  - Alnico is a mix of aluminium, nickel and cobalt, and it is used to make permanent magnets.

- **Aluminium Alloys**
  - AA-8000: used for building wire
  - Al-Li (aluminum, lithium, sometimes mercury)
  - Alnico (aluminum, nickel, copper)
  - Duralumin (copper, aluminum)
  - Magnalium (aluminum, 5% magnesium)
  - Magnox (magnesium oxide, aluminum)
  - Nambe (aluminum plus seven other unspecified metals)
  - Silumin (aluminum, silicon)
  - Zamak (zinc, aluminum, magnesium, copper)
  - Aluminum forms other complex alloys with magnesium, manganese, and platinum
- **Bismuth Alloys**
  - Wood's metal (bismuth, lead, tin, cadmium)
  - Rose metal (bismuth, lead, tin)
  - Field's metal
  - Cerrobend

- **Cobalt Alloys**
  - Megallium
  - Stellite (cobalt, chromium, tungsten or molybdenum, carbon)
  - Talonite (cobalt, chromium)
  - Ultimet (cobalt, chromium, nickel, molybdenum, iron, tungsten)
  - Vitallium
- **Gallium Alloys**
  - Galinstan (gallium, indium, tin)
- **Gold Alloys**
  - Electrum (gold, silver, copper)
  - Tumbaga (gold, copper)
  - Rose gold (gold, copper)
  - White gold (gold, nickel, palladium, or platinum)
- **Indium Alloys**
  - Field's metal (indium, bismuth, tin)
- **Mercury Alloys**
  - Amalgam (mercury with just about any metal except platinum)

- **Lead Alloys**
  - Antimonial lead (lead, antimony)
  - Molybdochalkos (lead, copper)
  - Solder (lead, tin)
  - Terne (lead, tin)
  - Type metal (lead, tin, antimony)
- **Magnesium Alloys**
  - Magnox (magnesium, aluminum)
  - T-Mg-Al-Zn (Bergman phase)
  - Elektron
- **Tin Alloys**
  - Britannium (tin, copper, antimony)
  - Pewter (tin, lead, copper)
  - Solder (tin, lead, antimony)
- **Titanium Alloys**
  - Beta C (titanium, vanadium, chromium, other metals)
  - 6al-4v (titanium, aluminum, vanadium)
- **Uranium Alloys**
  - Staballoy (depleted uranium with titanium or molybdenum)
  - Uranium may also be alloyed with plutonium

- **Rare Earth Alloys**
  - Mischmetal (various rare earths)
- **Potassium Alloys**
  - KLi (potassium, lithium)
  - NaK (sodium, potassium)
- **Zinc Alloys**
  - Brass (zinc, copper)
  - Zamak (zinc, aluminum, magnesium, copper)
- **Silver Alloys**
  - Argentium sterling silver (silver, copper, germanium)
  - Billon (copper or copper bronze, sometimes with silver)
  - Britannia silver (silver, copper)
  - Electrum (silver, gold)
  - Goloid (silver, copper, gold)
  - Platinum sterling (silver, platinum)
  - Shibuichi (silver, copper)
  - Sterling silver (silver, copper)

- **Nickel Alloys**
  - Alumel (nickel, manganese, aluminum, silicon)
  - Chromel (nickel, chromium)
  - Cupronickel (nickel, bronze, copper)
  - German silver (nickel, copper, zinc)
  - Hastelloy (nickel, molybdenum, chromium, sometimes tungsten)
  - Inconel (nickel, chromium, iron)
  - Monel metal (copper, nickel, iron, manganese)
  - Mu-metal (nickel, iron)
  - Ni-C (nickel, carbon)
  - Nichrome (chromium, iron, nickel)
  - Nicrosil (nickel, chromium, silicon, magnesium)
  - Nisil (nickel, silicon)
  - Nitinol (nickel, titanium, shape memory alloy)
- **Zirconium Alloys**
  - Zircaloy (zirconium and tin, sometimes with niobium, chromium, iron, nickel)

- **Iron or Ferrous Alloys**
- Steel (carbon)
    - Stainless steel (chromium, nickel)
        - AL-6XN
        - Alloy 20
        - Celestrium
        - Marine grade stainless
        - Martensitic stainless steel
        - Surgical stainless steel (chromium, molybdenum, nickel)
    - Silicon steel (silicon)
    - Tool steel (tungsten or manganese)
    - Bulat steel
    - Chromoly (chromium, molybdenum)
    - Crucible steel
    - Damascus steel
    - HSLA steel
    - High speed steel
    - Maraging steel
    - Reynolds 531
    - Wootz steel

- Iron
    - Anthracite iron (carbon)
    - Cast iron (carbon)
    - Pig iron (carbon)
    - Wrought iron (carbon)
- Fernico (nickel, cobalt)
- Elinvar (nickel, chromium)
- Invar (nickel)
- Kovar (cobalt)
- Spiegeleisen (manganese, carbon, silicon)
- Ferroalloys
    - Ferrochrome (chromium)
    - Ferromagnesium
    - Ferromanganese
    - Ferronickel
    - Ferrophosphorus
    - Ferrotitanium
    - Ferrovanadium
    - Ferrosilicon

- **Aluminum Alloys**
  - Aluminum is not a very strong metal, but its conductive qualities make it useful for a variety of applications.
  - For this reason, manufacturers mix aluminum with other metals to strengthen it, forming several different aluminum alloys.
  - Alloys using aluminum include alnico, which contains nickel, iron and cobalt; magnalium, which contains magnesium and duraluminium, also known as duralumin and duralium, which contains copper and, in some instances, magnesium and manganese.
  - While manufacturers use alnico in the production of magnets, they use magnalium primarily in instruments.
  - Duraluminium is often a component in car and aircraft engines.

- **Copper Alloys**
  - The element copper is prone to oxidation, which makes it surface turn a dull, pale-greenish color.
  - To prevent oxidation, and to increase its strength, manufacturers fuse copper with several different elements.
  - One of the most common copper alloys is brass, which contains approximately 20 percent zinc.
  - Manufactures often use the alloy for decorative items such as jewelry, as well as for nuts and bolts.
  - Another common copper alloy is bronze, which contains about 10 percent tin.
  - Nowadays, people commonly use bronze for making coins, statues and, as with copper, decorative items.

- **Iron Alloys**
  - The most well-known alloy of iron is steel, which can contain from 0.5 percent to 1.5 percent of carbon as its supplemental element.
  - The carbon helps prevent the iron from rusting, and makes it stronger. People use the material widely in construction, such as for making screws, nails and beams for buildings and bridges.
  - A variation on the alloy is stainless steel, which also contains nickel and chromium in addition to carbon.
  - These elements help keep the metal shiny and intensify its resistance to corrosion.
  - Manufacturers use stainless steel in a variety of different applications, such as for building tools, eating utensils, furniture and appliances such as refrigerators and ranges.

- **Gold Alloys**
  - As a soft metal, pure gold is easy to work.
  - For this reason, jewelry makers often mix it with other elements to increase its strength.
  - The most common gold alloys include yellow gold, which contains copper, silver -- and in some instances cobalt -- and white gold, which contains copper, zinc, nickel and, in some instances, palladium.
  - All types of jewelry, such as rings, bracelets, necklaces and earrings consist of both these alloys

Types of coatings to reinforcement

- Protective anticorrosive coatings to steel reinforcement before it is laid in concrete can guard against corrosion of steel rebars.
- Four different coating systems are available.
  - They are metallic coatings which give sacrificial protection to steel reinforcement,
  - insulating type of coating,
  - passivating type of coating based on cement and
  - barrier-cum-passivating-type of coating.
- **Metallic coatings** include hot dip galvanizing, copper and nickel coatings.
- Fusion bonded epoxy coating, chlorinated rubber coating, coal tar epoxy coating and asphalt coating are **insulating type of coatings**.
- **Passivating type of coatings** comprise of inhibited and sealed cement slurry and cement polymer anticorrosive coating.
- The cement polymer composite coating is a **barrier-cum passivating-type of coating.**

Composite material

- Composite materials are commonly classified at following two distinct levels:
- The first level of classification is usually made with respect to the matrix constituent.
- The major composite classes include **Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs).**
- The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.
- The second level of classification refers to the reinforcement form - **fibre reinforced composites**, **laminar composites** and **particulate composites**.

Plastics

- Plastics are made from resin with or without fillers, plasticisers and pigments.
- These are organic materials of high molecular weight which can be moulded to any desired form when subjected to heat and pressure in the presence of a catalyst.
- Schonbein invented a plastic named cellulose in 1846.
- Later John Wesley Hyatt in 1890 developed cellulose, and Adolph spitter invented casein plastics.
- Bakelite was developed in 1909 by Dr. Bakeland. Since then a variety of plastics have been developed.
- These are natural (shellac and resin) or synthetic in origin.
- Plastics are replacing glass, ceramics and other building materials due to the low temperature range in which they can be brought to the plastic state and the consequent ease of forming and fabrication and also for their low cost and easy availability

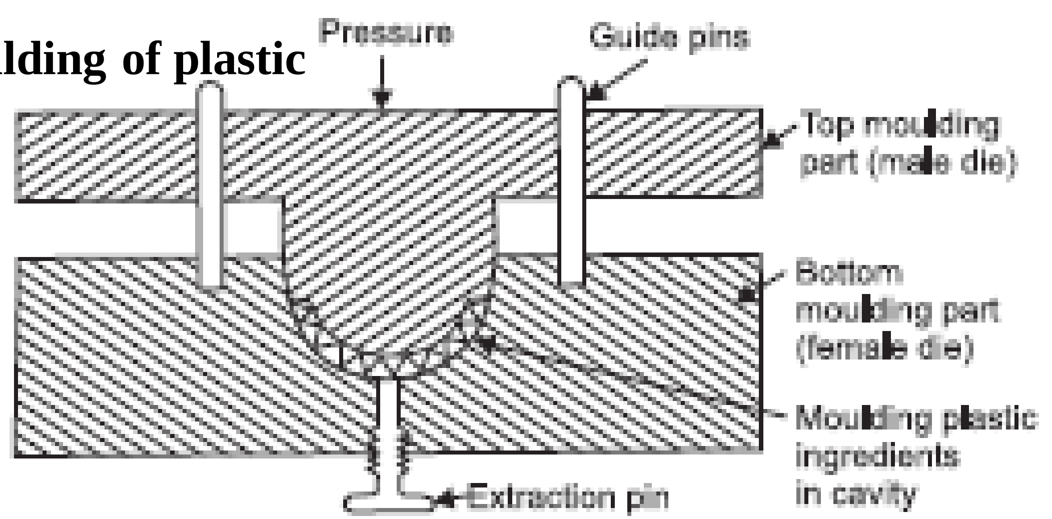
Types of plastic

- Plastics are classified as thermoplastic, and thermosetting.
  - The **thermoplastic** variety softens on heating and hardens on cooling, *i.e.*, their hardness is a temporary property subjected to change with rise or fall of temperature and can be brought again to plastic stage on heating.
  - These are formed by addition polymerisation and have long chain molecular structure.
  - They can be remoulded, for use, as many times as required.
  - Examples are material resins— rosin, kopal, amber, shellac; cellulose derivatives— cellulose acetate, cellulose nitrate, nitrocellulose or celluloid, cellulose acetate-butyrate; polythenic or vinyl resin—polyethylene, polyvinyl chloride, polyvinyl acetate, vinyl chloride = vinyl acetate, poly vinylidene chloride, polystyrene, polymethyl methyacrylate or lucite or plexiglass and polytetrafluoroethylene; polyamides Nylon 6:6, Nylon 6 and Nylon 11

Compression moulding

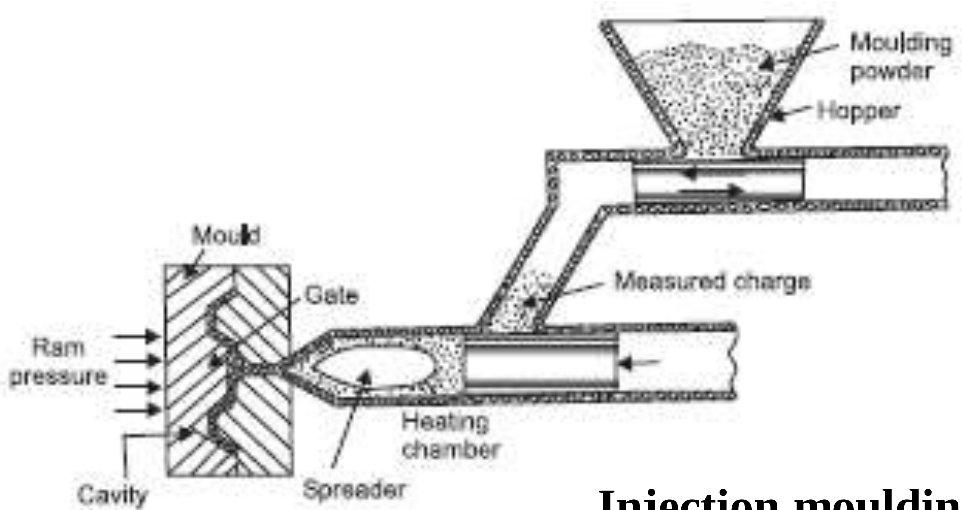
- Compression moulding can be employed both for the thermoplastics and thermosetting plastics.
- The fluidised material is filled in the mould cavity by hydraulic pressure (Figure). There is an arrangement to heat the plastic if desired. Temperature and pressure is applied till the chemical reaction is complete.
- Finally curing is done by heating (thermosetting plastics) or by cooling (thermoplastics). After curing is complete, mould is opened and moulded material is taken out.

Compression moulding of plastic



Injection moulding

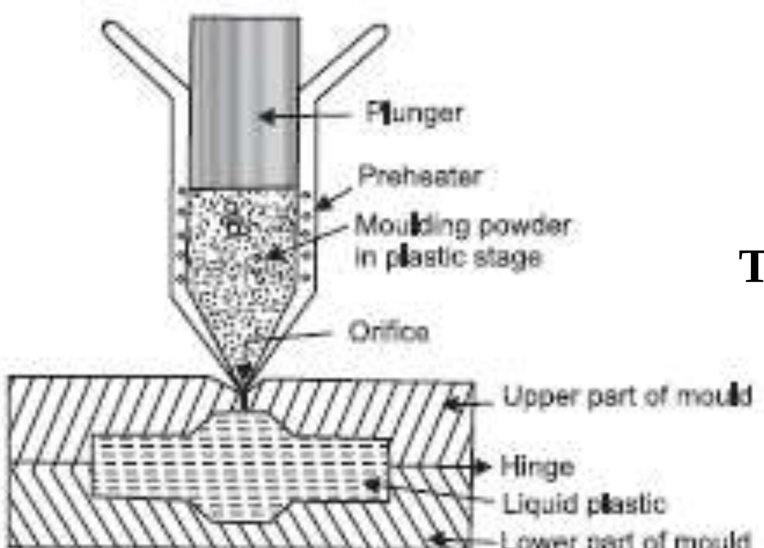
- Injection moulding is best suited for the moulding of thermoplastic materials.
- The plastic powder is fed into a cylinder from a hopper where it is heated. When the mould opens, a screw (Fig.16.12) or a plunger allows the material to go inside the cylinder from the hopper.
- The resin melts in the heating zone from where it is sent to the mould cavity through nozzle.
- The mould is kept cold to allow the hot plastic to cure and acquire the shape. Half of the mould is opened to cause enjection of the finished article.



Injection moulding

Transfer moulding

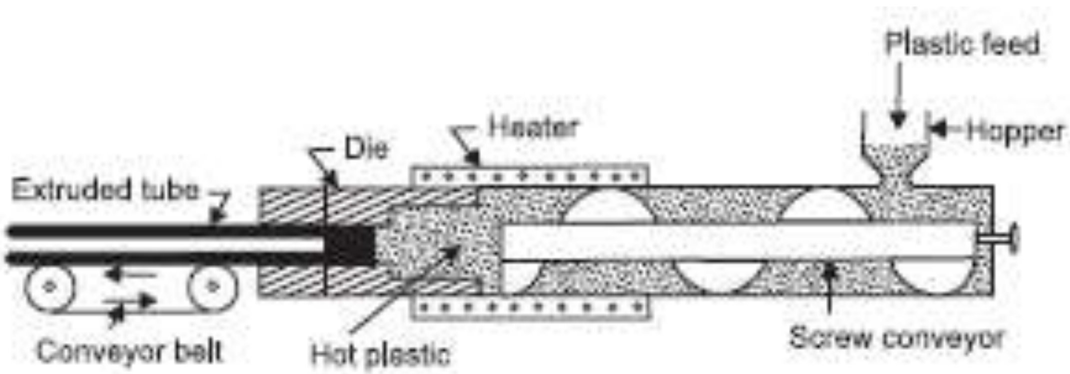
- Transfer moulding uses the principle of injection moulding for thermosetting materials. Intricate machine parts are moulded by this method.
- The thermosetting material powder is heated to become just plastic and injected through an orifice, as shown in Fig. 16.13, into the mould by the plunger working at high pressure.
- The temperature of the material rises because of the friction at the orifice and the powder becomes almost liquid which flows into the mould and in turn is heated to curing temperature.



Transfer moulding of plastic

Extrusion moulding

- Extrusion moulding is used for continuous moulding of thermoplastic materials into articles of uniform cross-section such as tubes, rods, strips, electric cables, etc.
- The thermoplastic material is heated to plastic state and is pushed to a die by a screw conveyer (Fig. 16.14 and Fig. 16.15).
- As the extruder rotates it has a mixing, smearing, and frictional heating action which changes the dry granular charge into a soft plastic mass before it reaches the end of the screw. Here the plastic mass by air jets.



Moulding of tube by horizontal extrusion moulding

Blow moulding

- Air pressure or vacuum are employed in this method of moulding to force the softened plastic powder into the mould.

Casting

- The plastics are moulded without application of pressure.
- The resin is melted and poured into mould.
- The casting of plastics is similar to that of cast iron. Since the cast plastic is not so smooth just after casting, they are polished. This method is most suited to the plastics formed form cellulose acetate and cellulose nitrate.

Lamination

- Thin sheets of cloth or paper asbestos are impregnated with thermosetting resin.
- These lamins are then pressed by a hydraulic press. Under temperature and pressure the lamins are bonded together to form one sheet.
- The laminated plastics exhibit improved mechanical and electrical properties.
- The thickness of laminated plastics ranges between 0.13 mm–15 mm. Vinyl resin is most suitable for lamination.

Glass fibre reinforced polymers

- Glass fibre – reinforced polymer (GFRP) also fibre- reinforced polymers is a composite material made of a polymer reinforced with fibre.
    - The fibres are usually glass carbon, aramid although other fibre such as paper or wood have been sometimes used.
    - GFRPs are commonly used in the aerospace, automotive, marine, and construction industries.

Geo - synthetics

- Geo-synthetics are synthetic products used to stabilize terrain.
- They are generally polymeric products used to solve civil engineering problems.
- The polymeric nature of the products makes them suitable for use in the ground where high levels of durability are required.
- They can also be used in exposed application.
- Geo-synthetics are available in a wide range of forms and materials.
- These products have a wide range of application and are currently used in many civil, geotechnical, transportation, geo-environmental, hydraulic, and private development applications including roads, airfields, railroads, embankment, retaining structures, reservoirs, canals dams, erosion control, sediment control, landfill liners, landfill covers, mining.

- TYPES OF GEOSYNTHETICS
  - **Geotextiles**
  - **Geogrids**
  - **Geonets**
  - **Geomembranes**
  - **Geosynthetic Clay Liner (GCL)**
  - **Geocells (3-d confinement)**
  - **Geocomposites & Geo-others**

Geosynthetic Clay Liners

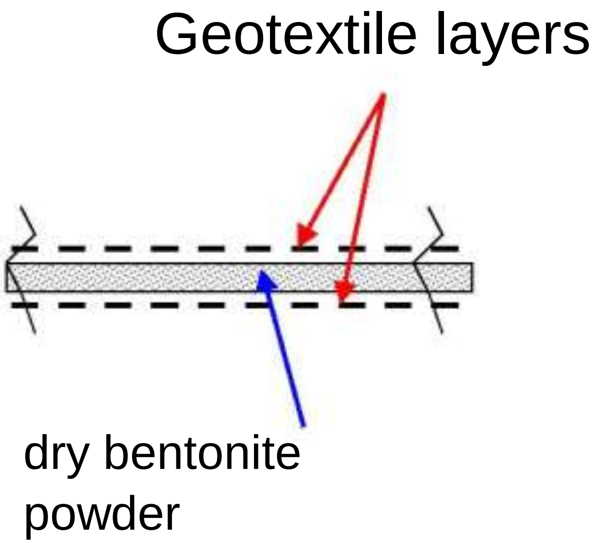
- Consist of a core of bentonite clay sandwiched between layers of thick non-woven geotextile

- Applied below and above geomembrane layers in landfills

- Self-repair mechanism

- Bentonite expands when flid leaks through punctured geomembrane – closes the gap

Geosynthetic Clay Liner



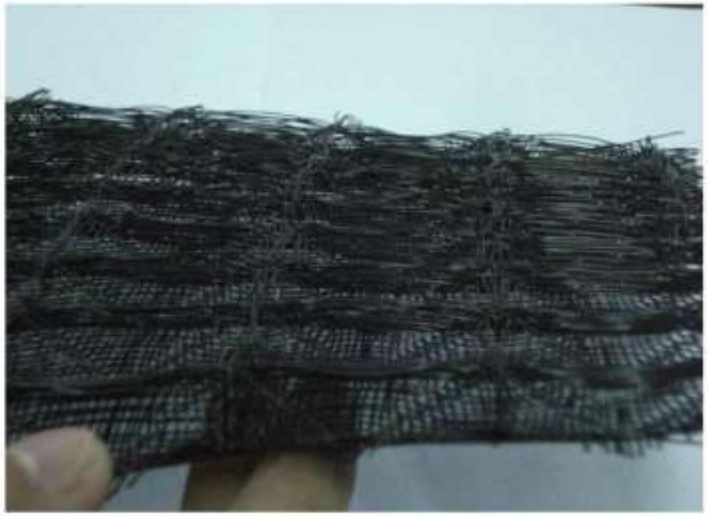
Advantages

- Easy to transport
- Any fill material can be used
- All round confinement to soil
- Semi-rigid layer (very stiff support)
- Spreads loads over a large area
- Excellent support even under cyclic loads.

APPLICATIONS

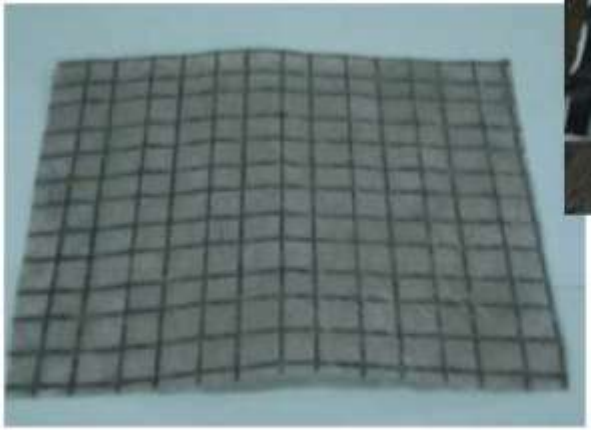
- Erosion control
- Steep slopes and retaining walls
- Sub-base support
- Road bases
- Railway tracks
- Container yards

Polymeric erosion control mats



Geocomposites

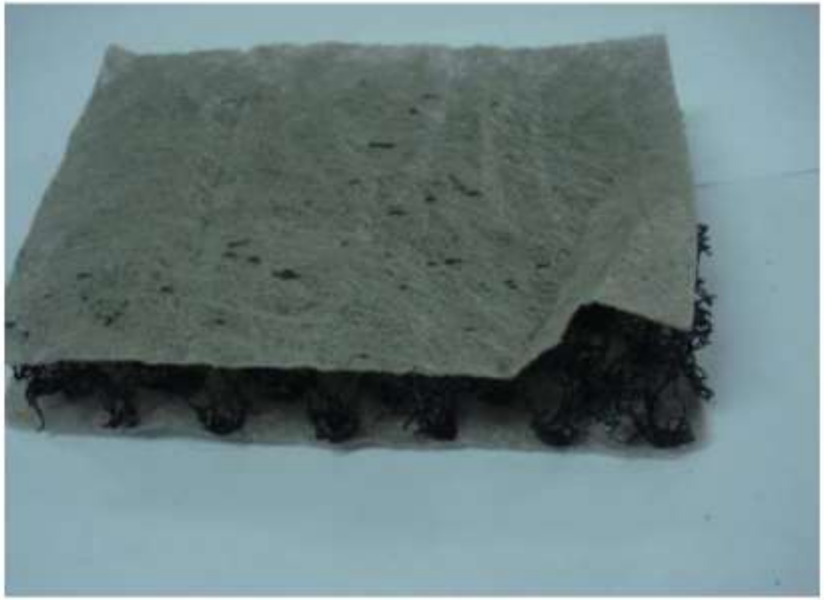
- Combination of two different types of geosynthetics to take advantage of each



Geo-others

- Geodrains
- Lightweight fills
- Geopipes
- Geotextile bags & soil encapsulation
- Gabions
- Geosynthetic Encased Stone Columns
- Many others – left to the imagination of engineers

Drainage boards for use in Retaining Walls

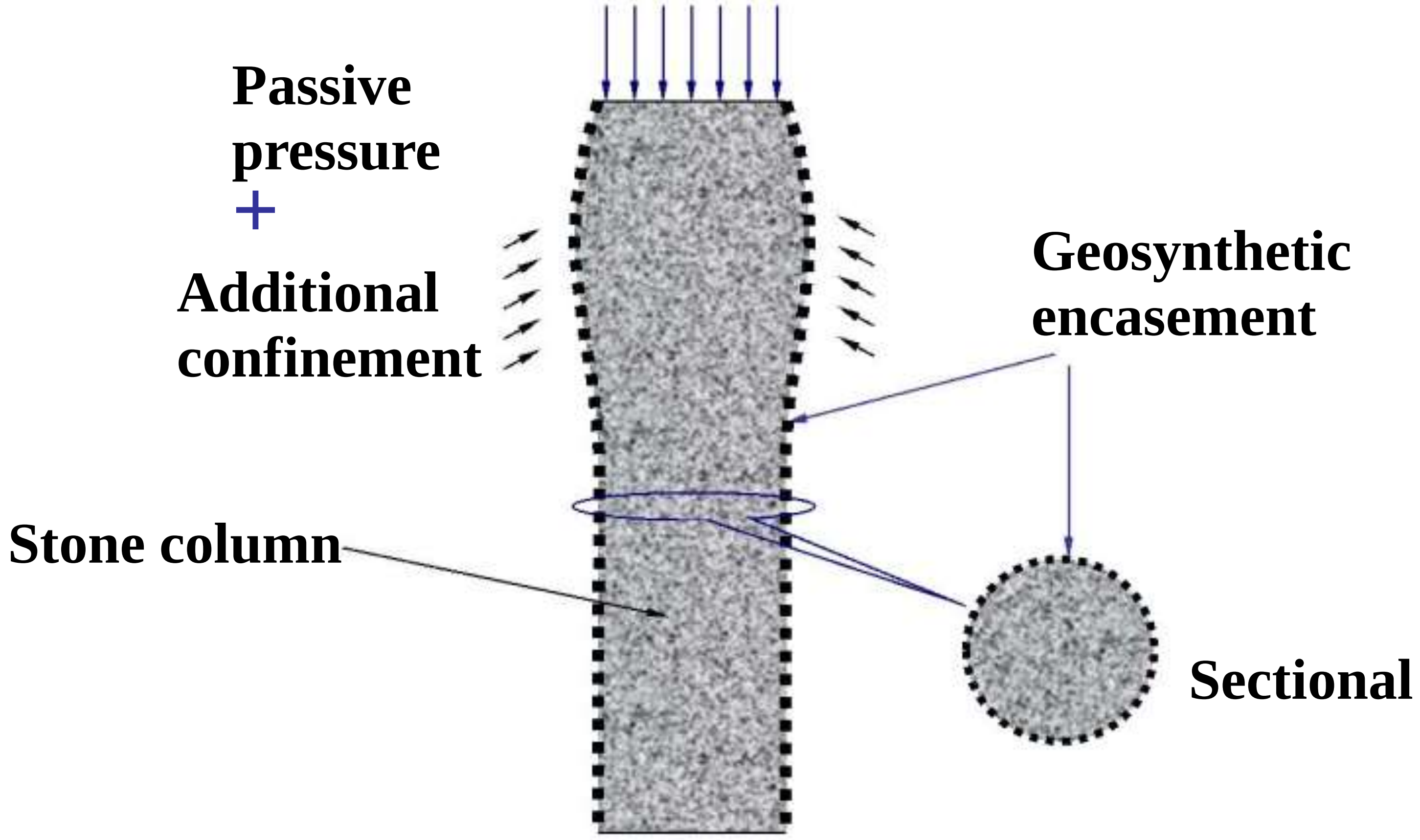


Light-weight drainage medium

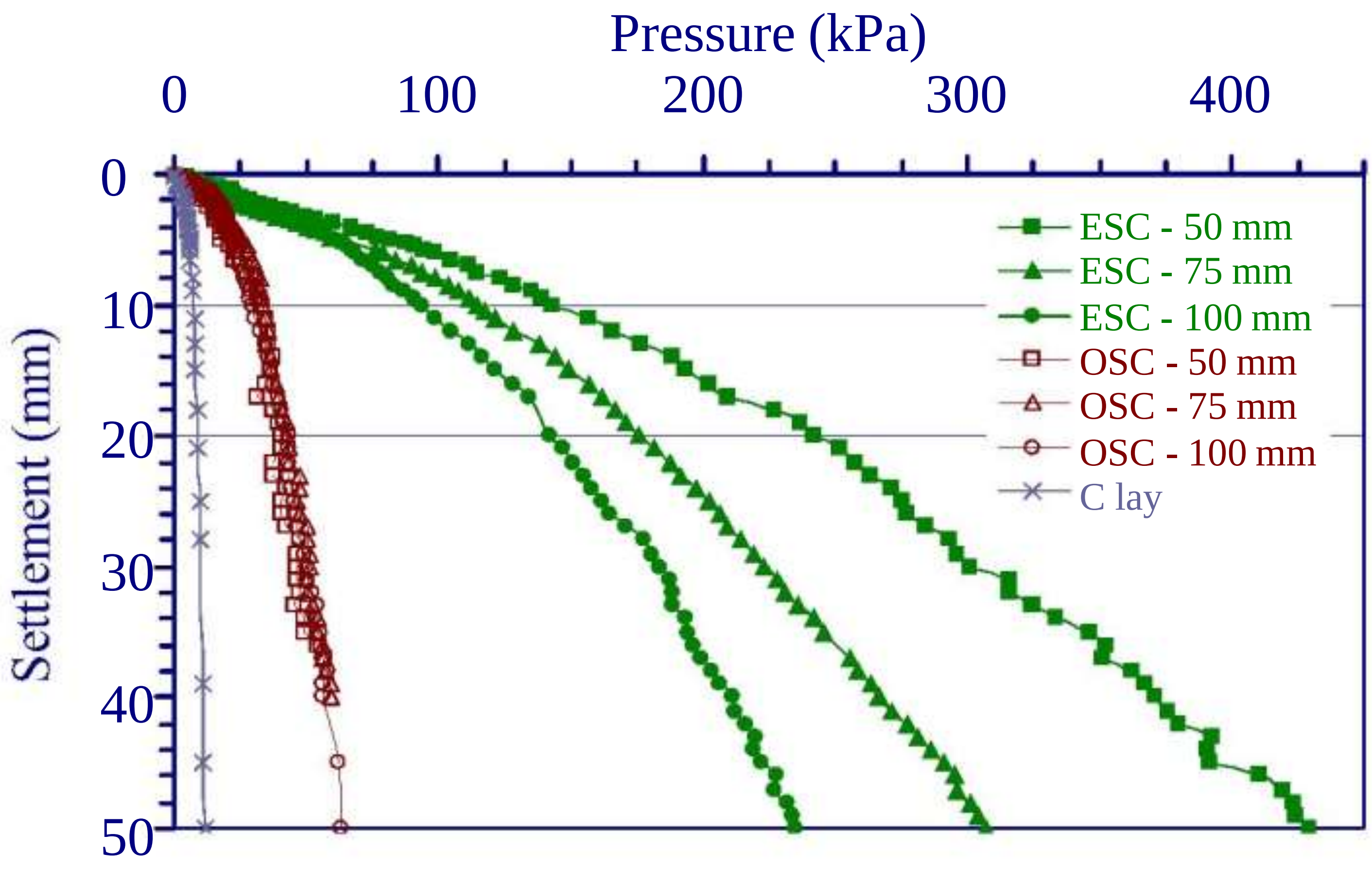
Made of used rubber tyres and other industrial wastes

Encased Stone Column

Bearing capacity enhanced by



Load settlement curve for stone columns encased in non-woven geotextile



Polymers

- Polymer materials account for the highest growth area in construction materials.
- In basic terms, polymers are very long molecules typically made up of many thousands of repeat units.
- They include plastics, rubbers, thermoplastic elastomers, adhesives, foams, paints and sealants.
- Well established applications of polymers in construction include areas such as flooring, windows, cladding, rainwater, pipes, membranes, seals, glazing, insulation and signage.
- With thousands of commercially available polymers new applications are continuously emerging.

Polymers

- Confidence in the performance and properties of construction materials has always been important and may be of particular interest for polymers, which are relatively new compared to traditional material types that have been in use for hundreds or thousands of years.
- The introduction of polymeric materials can bring new concerns particularly relating to their longevity, how they will be affected by general ageing and weathering, the effects of pollution and what will happen to them at their end of life.
- Examples of polymer materials in construction applications is shown in following table.

Heat insulating material

- The purpose of thermal insulation is to restrict the heat transfer from warmer to cooler areas.
- The commonly used heat insulating materials work on principle of either air spaces formed between structural components, surface insulation or internal insulation.
- Well known products are aerated concrete, gypsum boards, fibre boards, asbestos cement boards, chip boards, cork boards, foam plastic, aluminium foil, reflecting paints, expanded blast furnance slag, vermiculite*, fibre glass, glass wool, etc. Cavity wall, though costly, provides good insulation.

Heat insulating material

Properties

- Heat insulating material should be impermeable to water, fire proof, resists insect attacks, have low thermal conductivity (0.0228 kCals cm/m2°C).
- Since a good heat insulating material has porous structure the strength is lowered affecting its stability.

Sound insulating material

- A well designed building should incorporate sound insulation to restrain noise level.
- High noise conditions results in uncomfortable living conditions, mental strain, fatigue and may even lead to nervous break down or temporary deafness.
- Adequate insulation can be achieved by using sound absorbing or sound repellent materials.
- The commonly used sound insulating materials are cellular concrete, asbestos, rock wool, glass wool, glass silk, mineral wool boards, cane fibre and porous tiles.
- Acoustic plastics such as gypsum plaster is very effective in sound insulation.

Water proofing materials

- Dampness in a building is the main cause of the deterioration of the building as well as for the ill-health of the occupants.
- The main cause of dampness is the absorption of water by the materials because of high ground water table, rain, exposed top of parapet walls, inadequate slope of roof, pounding of water in adjoining areas of the structure and condensation.
- The damp-proofing of a building is done by interposing a layer of damp-proofing material between source of dampness and building and this layer is known as *damp-proofing course* (D.P.C.).
- The principle of damp-proofing is to provide D.P.C. horizontally or vertically without any break and thought the thickness of wall.
- A good water-proofing material should be impervious, durable and should be able to resist loads to which it will be subjected.
- It should be in position to accommodate some structural movement without fracture.

Water proofing materials

- The materials commonly used to check dampness can be divided into the following four categories:
  1. *Flexible materials* the examples are bitumen felts, plastic sheeting (Polythene sheet) etc.
  2. *Semi-rigid materials* the examples are mastic asphalt or a combination of materials or layers.
  3. *Rigid materials* the examples are first class bricks, stones, slates, cement concrete etc.
  4. *Grout* consists of cement slurry and acrylic based chemicals/polymers.
- The choice of a material to function as an effective damp-proof course requires a judicious selection.
- It depends upon the climatic and atmospheric conditions, nature of structure and the situation where D.P.C. is to be provided.

Surface preparation materials

- The preparation of surfaces or surface preparation is one of the most important steps or processes when performing an adhesive bonding.
- It will not help the efforts invested during the design, selection and validation of the adhesive, if we do not make a good surface preparation on the surface that we will put the adhesive.
- There are different methods, processes or techniques on surface preparation, the choice of either technique depends on:
  - The type of material of the substrate (metal, ceramic, glass or plastic)
  - The type of adhesive used to bond the substrates.
  - The surface conditions of the substrates (surfaces with oils, rusted surfaces, surfaces with dust ...)

- **Surface cleaning.**

  - The surface cleaning is used to eliminate all types of contaminants found on the surface of the substrates.

  - The contaminants are foreign agents that are weakly bonded to the substrate, the presence of these contaminants adversely affects the adhesion and wetting of the adhesive, if the adhesion occurs the connection system fails, due to the weak adhesion and cohesion of the contaminant to the substrate.

  - For surface cleaning we can use organic solvents or aqueous cleaners, the choice will depend on the type of material to be cleaned and the conditions in which the surface is clean.

- **Surface Post-treatment**

- The post-treatment of surfaces is set of chemicals materials (activators and primers) used in conjunction with the adhesive during the application phase and are intended to:

  - Create active surface on the substrate.
  - Generate compatible surfaces with the adhesive resin
  - Reduce surface roughness
  - Each of the points mentioned above increases the wetting properties and adhesion between the substrate and the adhesive.

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