CHAPTER 06

Structural Steel & Other Construction Materials

6.1 Introduction

- Metals are used extensively in structures.
- Metals which are used for engineering purposes are called as ferrous metals with iron as the main constituent. e.g. Wrought iron, cast iron, stainless steel etc.
- Other type of metals include non-ferrous metals like copper, zinc, tin, lead etc. wherein iron is not the main constituent.

6.2 Ferrous Metal

- Iron is an element with atomic number 26 and occurs in four different allotropic forms viz. α, β, γ and δ.
- α iron is weak and ductile, possess magnetic properties and is unable to dissolve carbon and forms bcc (body centered cubic) structure.
- β iron is hard, brittle, non - magnetic and dissolves carbon.
- γ iron is very similar to β iron and forms fcc (face centered cubic) structure.
- δ iron is non-magnetic and absorbs very little carbon.
- γ iron containing carbon is called as austenitic and α iron containing carbon is called as ferritic.

6.2.1 Iron

- Iron is the most important and widely used structural material with abundant availability but not in pure form but instead with other minerals.
- The major ores of iron with percentage iron in them are as follows:

Haematite (Fe_2O_3)	-	70%
Magnetite (Fe_3O_4) – 70	-	75%
Limonite ($2Fe_2O_3.3H_2O$)	-	60%
Iron pyrite (FeS_2)	-	47%
Siderite ($FeCO_3$)	-	40%

- The principle of extracting iron from any type of iron ore is the same i.e. heating the ore in presence of a reducing agent resulting in the formation of CO and/or CO_2, liberated gasses and the pure iron.
- Iron alloys freely with other elements and its properties can be altered by varying the composition of constituents (mainly carbon).

6.2.2 Pig Iron

- It is the iron that is obtained from the blast furnace. The iron ore is crushed into smaller pieces and the ore is then calcined to remove the moisture.
- This calcined ore is smelted in the blast furnace where iron gets reduced.
- Limestone is added as flux to remove sulphur, ash etc. This flux combines with the fuel ashes and impurities in the iron ore to form fusible products which separate out from the metal as slag.
- Pig iron is the very first form of iron which is then subjected to various metallurgical processes to add different percentages of carbon and other materials to form different ferrous metals like cast iron, wrought iron, steel etc.
- Composition: Pig iron contains 3 - 4% carbon, 0.5 - 3.5% silicon, 0.5 - 2% manganese, 0.02 - 0.1% sulphur and 0.03 - 1% phosphorous.
- Properties:
  - It is hard and brittle and melts easily at 1200°C.
  - It cannot be magnetized but can be hardened.
  - It has high compressive strength but is weak in tension and shear.
  - Pig iron does not rust and riveting/welding cannot be done.
- Uses:
  - It is used for making base plates, columns, door brackets etc.

6.2.3 Cast Iron

- Pig iron obtained from the furnace is re-melted with limestone (as flux) and coke in a furnace (Cupola furnace).
- The molten metal obtained from furnace is poured into moulds of desired size. This product is called as cast iron.
- Cast iron contains 2 - 4% carbon in two forms viz. (i) in a state of chemical combination as combined carbon (known as cementite) and (ii) as free carbon (as graphite) in the mixture.
- Thus quality of cast iron depends on the state of carbon in which it exists.

Difference between steel and cast iron:

Steel is plastic and forgeable while cast iron is neither plastic nor forgeable.

6.2.3.1 Cast Iron: Methods of Casting

- Sand casting: Here the molten metal is poured into a cavity in a mass of packed sand.
  - Wooden patterns are used for making the moulds which are removed when sand gets dried up Each mould is provided with a hole for casting through which the molten iron is poured
  - Another hole is also provided for the escape of air and other hot gases.
  - After the iron gets cooled, the mould is broken up and cast iron is taken out.
- Hollow casting: Here a solid core is placed where the hollow is required.
  - After casting, the core and the mould are taken out.
  - Casting material becomes hollow due to the core.
  - This method is used for casting columns and piles.
- Vertical sand casting: Here the mould box and the sand core are kept in the vertical position. Upon cooling, the core is taken out by crane. This method is used in the manufacture of pipes.
- Centrifugal casting: In ordinary casting, many blow holes are left because of little control over temperature and sand mould. This is overcome by centrifugal casting.
  - Here molten metal is poured in a revolving metallic cylinder in a controlled manner at about 10,000 rpm.
  - This method gives dense casting with fine grained structure having uniform physical properties.
  - This method is used for casting large diameter pipes, gun barrels etc.
- Die casting: This casting is done under pressure of about 140 x 10^6 N/mm^2.
  - The die is cooled with the application of water and thus the metal solidifies quickly thereby facilitating early removal of casting.
  - This method is quite suitable for commercial purposes since it is cheap as compared to other methods of casting.

6.2.3.2 Properties of Cast Iron

- It is hard and brittle with specific gravity of 7.5.
- It can neither be riveted/bolted nor welded.
- It is strong in compression (600 N/mm^2) but is weak in tension (150 N/mm^2) and shear.
- It has low melting point (1200°C) and gets affected by sea water.
- It cannot be magnetized and is not suitable for forging.
- Cast iron containing large amount of chromium and manganese is having a permanently white colour while that containing high silicon is grey in colour.

6.2.3.3 Impurities in Cast Iron

- Carbon: It influences most the physical and mechanical properties of cast iron.
  - As percentage of carbon increases, the melting temperature of cast iron reduces.
  - As carbon content in cast iron increases, shrinkage reduces.
- Silicon: Silicon when present in minute amounts (0.5-3%) increases the fluidity of molten cast iron, decreases the blow holes and increases the density of castings.
  - It reduces the solubility of carbon in iron.
  - It reduces shrinkage of cast iron.
  - When silicon content is increased up to 6% then iron becomes hard and has mirror like fracture.
- Sulphur: It is highly undesirable in cast iron and is limited to 0.1%.
  - It combines with manganese to form manganese sulphide (MnS). In case manganese is very low in quantity so that it becomes deficient for sulphur then sulphur combines with iron to form iron sulphide (FeS).
  - These sulphides solidify at very low temperatures than the cast iron and thus tend to make the cast iron brittle and weak at higher temperatures.

- High sulphur content makes the iron brittle and hard and increases shrinkage. This is neutralized by the addition of silicon.

- **Phosphorous:** It has no considerable effect on cast iron when present in amount which is less than 0.5% but usually it is present in the range of 0.1-1.5%.
  - Phosphorous when present in amount more than 2%, makes the cast iron brittle and reduces its strength.
  - High phosphorous iron is much more fluid and is suitable for ornamental castings.
- **Manganese:** Manganese when present in the range of 0.4-1.2%, combines with sulphur followed by carbon to form manganese carbide.
  - It increases the hardness and tensile strength of steel.
  - Manganese increases the solubility of carbon in iron and reduces liberation of graphite.
  - Excess of manganese increases shrinkage of iron.

Table : Types of cast iron

S.No.	Type	Properties	Composition (%)	Uses
1.	Grey	Good machine- ability, low melting point, rusts easily in air, susceptible for acid attack, grey coloured	Carbon 2.5-3.75 Silicon 1-2 Manganese 0.4-1 Sulphur 0.06-1.2 Phosphorous 0.1-1	Pipes, fittings, locomotive wheels etc.
2.	White	Hard, brittle, difficult for machining, silvery white coloured	Carbon 1.75-2.3 Silicon 0.5-0.9 Manganese 0.15-0.5 Phosphorous 0.2-0.7 Sulphur 0.15-0.25	For manufacturing malleable iron, wrought iron etc.
3.	Malleable	Obtained from cast iron by partial removal of Mn, C, Si, P and S. Available as white and black hearth varieties	Carbon 2.2-3.6 Silicon 0.4-1.1 Phosphorous 0.1	Automobile, agricultural equipments, rail – road engineering equipments etc.
4.	Mottled	Obtained by heating cast iron with powdered haematite, high toughness, fractured surface shows grey and white patches		Small castings
5.	Chilled	Made by melting cast iron with 1/4" – ½ of its weight of wrought iron scrap		Roller and grinding mills, pistons, spokes etc.
6.	Toughened	Made by cooling cast iron rapidly which makes the outer surface hard		Studs

6.2.3.4 Uses of Cast Iron

- Due to low cost, strength and ease of melting and casting into various shapes, ease of machining and having high damping capacity, cast iron is widely used in engineering constructions and machines.
- It is used for making ornamental castings like lamp posts, wall brackets, bathroom fittings, chairs etc.

6.3 Wrought Iron

- It is obtained by removing impurities from the cast iron and is considered to be the pure iron.
- The total impurities are limited to 0.5% with maximum carbon content of 0.15%, silicon 0.15 - 0.2%, phosphorous 0.12 - 0.16%, sulphur 0.02 - 0.03%, manganese 0.03 - 0.1%.
- It is produced in a reverberatory (or puddling) furnace.
- The molten iron is first refined by blasting air in the furnace.
- The metal is then cooled down and poured into moulds. This metal becomes brittle.
- This metal is melted in furnace where the metal melts due to burning of gas.
- After melting, puddle balls are produced which are sent for shingling.
- The balls are sent to groove rollers to form flat bars. This process is repeated several times to remove the impurities.

6.3.1 Properties of Wrought Iron

- It is ductile, malleable, tough and is moderately elastic (modulus of elasticity 1.86 x 106 N/mm^2).
- Its ultimate compressive strength is about 200 N/mm^2 and tensile strength of about 40 N/mm^2.
- Transverse to the direction of rolling, the tensile strength ranges from 60 - 85% of its tensile strength in longitudinal direction.
- Melting point of wrought iron is 1500°C and specific gravity 7.8.
- Unlike cast iron, it can be forged and welded.
- It resists corrosion effectively.
- It is tough and can withstand shocks.
- At a temperature of about 900°C, it becomes so soft that its two pieces can be joined by hammering.
- Alloying elements that are used with wrought iron are nickel (Ni), copper (Cu) and molybdenum (Mo).
- Nickel in quantities of about 1.5 - 3.5% substantially increases the elastic limit and tensile strength.
- Nickel also helps in preventing the reduction of impact strength at sub-zero temperatures.
- Copper when added to wrought iron increases the corrosion resistance property.

6.3.2 Uses of Wrought Iron

- For making roof coverings, rivets, chimneys, gates etc.

6.4 Steel

- It is the most suitable building material among all the metallic materials.
- By suitably controlling the carbon content and other alloying elements and heat treatment, a desired combination of strength and ductility can be obtained.

On the basis of carbon content, steel is classifies as follows:

Table: Types of steel

S.No.	Type of Steel	Carbon content (%)
1.	Dead mild steel	< 0.15
2.	Mild Steel (MS)	0.15 – 0.3
3.	Medium carbon steel	0.3 – 0.8
4.	High carbon steel (or hard steel)	0.8 – 1.5 (>1% is called as cast steel or tool steel)

6.4.1 Properties and Uses of Various Types of Steel

6.4.1.1 Mild Steel

- It is also known as low carbon steel or soft steel.
- It is malleable, ductile, tough and more elastic than wrought iron.
- It can be forged and welded.
- It rusts quickly and can be magnetized permanently.
- Its specific gravity is 7.3, ultimate compressive strength is 800 - 1200 N/mm^2 and ultimate tensile strength is 600 - 800 N/mm^2.
- It is used for manufacturing rolled sections, reinforcing bars, roof coverings, sheet piles and rails.

6.4.1.2 High Carbon Steel

- Carbon content varies from 0.55 - 1.5%.
- It is also called as hard steel.
- It is tougher and more elastic than mild steel.
- It is difficult to forge and weld.
- Its ultimate compressive strength is 1350 N/mm^2 and ultimate tensile strength is about 1400-2000 N/mm^2 and specific gravity 7.9.
- It is used in pre-stressed concrete members and in RCC.
- Due to its ability to take shocks and thus it is used for making tools and machine parts.

6.4.1.3 High Tensile Steel

- Here the carbon content is about 0.6 - 0.8%, manganese 0.6%, silicon 0.2%, sulphur 0.05% and phosphorous 0.05%.
- It is a medium carbon steel.
- Its ultimate tensile strength is about 2000 N/mm^2 and minimum elongation of 10%.
- It is used in pre-stressed concrete construction.

6.5 Heat Treatment of Steel

- Heat treatment is given to steel in order to develop the desired properties in steel.
- The properties of steel can be controlled and changed by the various heat treatment processes.
- Two steel samples with same composition can be given different properties by different heat treatment process.
- Heat treatment is given to remove the gases, refine grain size, and relieve internal stresses and strains and to enhance the strength, ductility etc.

6.5.1 Types of Heat Treatment

1. Hardening
   - In this heat treatment, steel is heated above the upper critical temperature, holding it at that temperature for some time and then quenching it rapidly to produce a martensite structure.
   - Mazrtensite is the main constituent of hardened steel and is having fibrous and needle like structure.
   - Hardened steel is very brittle and cannot be used for practical applications.
   - The quenching medium is generally salt water, water or oil depending on the desired cooling rate.
   - This heat treatment is given in order to have a desired hardness up to a certain depth in steel.
2. Tempering
   - Hardened plain carbon steel is in its metastable condition or at equilibrium.
   - This hardened steel is re-heated at temperature below the critical temperature range which gives steel in stable condition.
   - Tempering is used to relieve the surface strains that develop when a thick piece of steel is cooled rapidly.
   - The tempering temperature varies from 100 to 700°C.
   - Higher the temperature of tempering, softer is the resulting steel.
3. Annealing
   - It is a general term applied for heating and slow cooling of metal or any other material which has developed strain due to rapid cooling.
   - Here steel is heated below a critical temperature such that strain re-crystallization occurs and then cooled down.
   - Normally the heating temperature ranges from 500 to 600°C.
   - Annealing imparts one or more of the following properties in steel:
     - It removes strain introduced due to rapid cooling.
     - It imparts softness, ductility and malleability.
     - It removes gases.
     - It modifies electrical, magnetic and other physical properties of steel.
4. Normalizing
   - Here steel is heated above critical range and cooling down rapidly in air but at a rate slower than critical cooling rate.
   - This heat treatment refines the grain structure resulting from rolling, forging and other manufacturing processes.

6.6 Rolled Steel Sections

- Steel sections can be rolled into various shapes and sizes in the rolling mills.
- Sections are rolled in such a way that it gives large section modulus with minimum cross sectional area.
- IS Handbook No. 1 gives various rolled steel sections such as I section, Tee section, channel section etc.

6.7 Reinforcing Steel Bars

- Concrete being weak in tension requires steel as reinforcement to take up the tensile stresses.
- Reinforcing bars are available in various diameters and steel grades.
- Effectiveness of reinforcing bar steel can be increased by the use of low alloy steel or by mechanical strengthening or by heat treatment.

- Mechanical strengthening is done by stretching, drawing, twisting etc.
- Heat treatment increases strength and improves mechanical properties of steel.

6.7.1 Types of Reinforcing Steel Bars

1. **Mild Steel**

Plain mild steel (designated as Fe 250) is more ductile than HYSD bars and absorbs shocks better.

- It is supplied as plain, round bars.
- IS 432 (Part - I): 1982 lays down specifications for mild steel bars.
- These bars are usually available in diameters ranging from 6 mm to 50 mm.

2. **High Yield Strength Deformed (HYSD) Bars**

These bars have ribs i.e. deformations on its surface which checks the longitudinal movement of bar in concrete.

- These bars form better bond with concrete.
- These do not have a definite yield point.
- HYSD bars result in higher tensile strength, bond strength and yield when twisted either hot or cold.
- Cold twisted bars are more suitable for building purposes.
- Cold twisted deformed bars are referred to as TOR steel bars.
- TOR steel is high strength deformed bars with high yield point and bond strength.

3. **Thermo-mechanically Treated (TMT) Bars**

These are extra strength reinforcing bars.

- Here steel bars receive a short intensive cooling as they pass through water cooling system after the last rolling mill stand.
- The lower temperature makes the outer surface hard.
- The process of intensive cooling is followed by cooling in atmosphere so that temperature of core is still hot.
- Thus the surface gets tempered by the heat coming from the core.
- Due to improved properties of high strength along with toughness and ductility, TMT bars are better than mild steel bars.
- TMT bars can resist temperature up to 500?C without any loss of strength.
- TMT bars are more ductile than cold twisted deformed bars.
- TMT bars have excellent bending property due to uniform elongation.
- These bars have very good weldability.
- They do not suffer the loss of strength at the welded joints.
- These bars can easily be welded with cold twisted bars.
- For these bars, no pre-heating or post-heating is required during the welding process.
- Because of high strength of surface layer, these bars resist fatigue loading and dynamic loading more efficiently.
- Since these bars are thermally hardened and thus are suitable at locations that are fire-prone because of thermal stability of the heat treated surface structure.
- These bars have high percentage of uniform elongation.
- They are highly recommended for high rise buildings due to saving involved in steel because of high strength.
- Now a days, we have thermo mechanically treated high strength corrosion resistant (TMT-HCR) bars.
- TMT-HCR bars are concrete embedded bars thereby giving superior resistance against aggressive weather conditions.
- TMT-HCR bars have high thermal resistance even at temperature of 600°C.

6.8 Alloy Steel

- All the desired properties in steel those are required for structures are not available in any single type of steel.
- In order to develop certain specific property (ies), a combination of metals or metallic substances is done which is called as an alloy.
- An alloy is a type of mixture of two or more metals.

Table : Different types of alloy steels

S.No.	Type of Alloy Steel	Composition	Properties	Uses
1.	Stainless steel	Chromium 16%	Hard, tough, elastic, acid resistant and rust proof	Utensils, ball bearings, dies etc.
2.	Nickel steel	Nickel 3.5%	More elastic, high tensile strength, more hardness and more ductility	Automobile and airplane parts
3.	Invar steel	Nickel 30-40%	Low coefficient of thermal expansion	Precision instruments, measuring tapes etc.
4.	Vanadium steel	Vanadium 0.1-2%	High tensile and yield strength, resistance to softening at high temperature	High speed tools, locomotive castings, chassis, automobiles etc.
5.	Tungsten steel	Tungsten 14-20%	High cutting hardness, abrasion resistant	Drilling machines, high speed tools etc.
6.	Manganese steel	Manganese 12-15%	Hard, tough, strong, difficult to machine, high electrical resistance	Railway points and crossings, milling equipments, crusher jaws roller etc.
7.	Molybdenum steel	Molybdenum 0.2-0.3%	High tensile strength at high temperature	Gears, axles, shafts etc.

6.9 Other Construction Materials

6.9.1 Stone

Stone is a natural, hard substance formed from minerals and earth material which are present in rocks. Stone can be classified as:

- Igneous rock
- Metamorphic rock
- Sedimentary rock

- **Igneous rock** is formed by the crystallization of molten magma for example granite. They are also known as primary, unstratified or eruptive rocks.
- **Metamorphic rocks** has undergone a change in structure, texture, or composition due to the natural agencies, as heat and pressure, especially when the rock becomes harder and more crystalline, as marble and slate.
- **Sedimentary rock** is formed by the deposition of sediment by glacial action, as limestone, sandstone and shale. They are also known as aqueous or stratified rocks.

Stone is used in construction in the following forms:

(a) Rubble (b) Dimension stone

(c) Flagstone (d) Crushed stone

(a) **Rubble** consists of rough fragments of broken stone that have at least one good face for exposure in a wall.

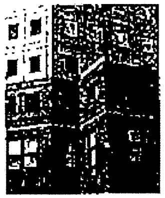
(b) **Dimension stone** is quarried and squared stone 2' or more in length and width and of specified thickness, used commonly for wall panels, cornices, copings, lintels and flooring.

(c) **Flagstone** refers to flat stone slabs used for flooring and horizontal surfacing.

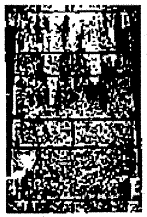
(d) **Crushed stone** is used as aggregate in concrete products.

A. Types of Building Stones

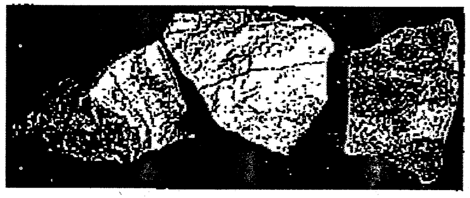
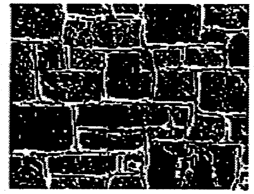
- **Argillite:** It is formed from clay, dark blue with faint shades of green. It is used for floor tile, stair threads, coping stones, interior wall base, interior window, stools of exterior and window sills.
- **Granite:** It is igneous origin, hard, strong, durable and capable of taking high pressure polish. Red, pink, yellow, green, blue, white and brown. It is used for flooring, wall paneling, column, mullion facing, stair threads and flagstone.

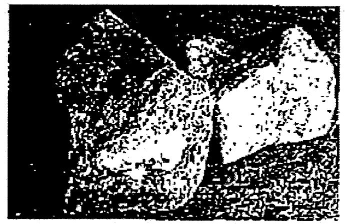
- **Limestone:** It is sedimentary rock like *dolomite* which have no cleavage lines, low in absorption, smooth, uniform in structure & composition. They have high compressive & tensile strength. It is used for wall & floor surfaces.

- **Travertine:** It is sedimentary rock, pleasing texture with small natural pockets on a cut surface. They are used for interior decorative stone.

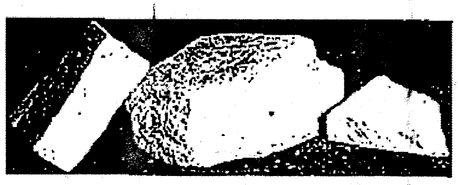
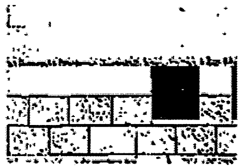



- **Marble:** It is metamorphic rock, a re crystallized limestone forming into *carrara, parian, onyx* and *vermont* types of marble. They are used for flooring, wall & column facing.

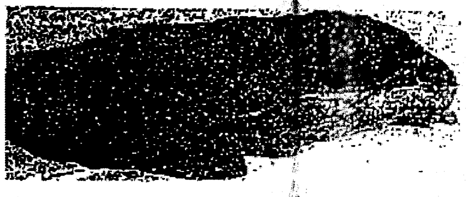


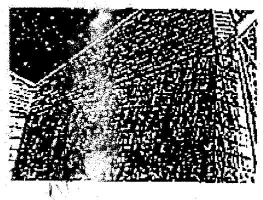

- **Serpentine:** It is igneous with mineral serpentine. Typically, olive green to greenish black but impurities may color the rock. It is used only for interiors due to weathering.

- **Sandstone:** It is class of rock of cemented silica grains with texture ranging from very fine to very coarse. Colors vary from buff, red and light brown. Porous where as 30% of volume composed of pores.

- **Slate Rock:** It is metamorphosis of clays and shale's deposited in layers. May be separated into thin, tough sheets called *slates*. Colors are black, green red, grey, or purple. It is used for flooring, window sills, stools, stair treads & facing





8. Stone Construction

Largely used as *facing* for building material with steel and concrete frames.

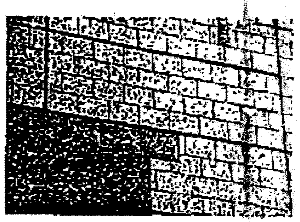
Application Categories :

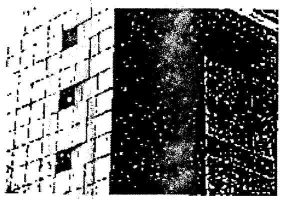
(a) Paneling (b) Ashlars

(c) Rubblework (d) Trim

(a) Paneling: Thin slabs of stone cut to dimension and thickness to cover back up walls and provide finished exterior. It can be done in following ways,

Running Bond is a masonry bond formed when all units are laid in stretcher position, with a half-unit overlap.

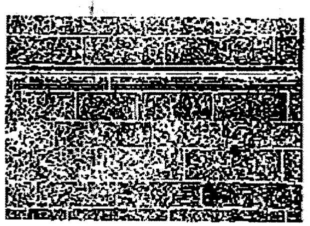




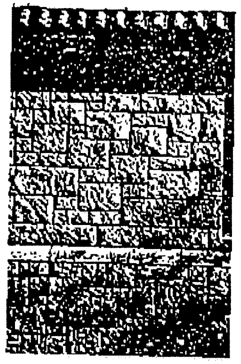
Stack Bond is a masonry bond formed when there is no overlapping of all units and all horizontal & vertical joints are aligned.

(b) Ashlars: It's work requires the use of cut stone that includes broken ashlars and are regularly or irregularly coursed.

Coursed Ashlar: Ashlar masonry laid out in courses of equal height; blocks of various sizes may be combined to make up the height of the course.

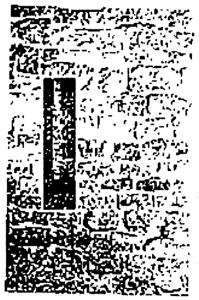


Random Ashlar: Ashlar masonry laid without regular courses but with an overall effect of horizontal orientation.



(c) Rubblework: Random and no attempt is made to produce an orderly course either horizontal or vertical. Small spaces are filled with smaller stones.

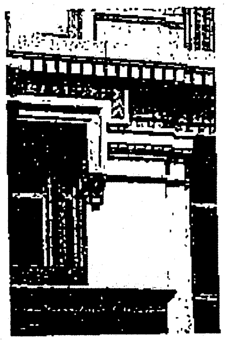
Coursed Rubble: Fieldstone or roughly dressed stone, with or without mortar, assembled to give a effect of courses.



Fieldstone: Stone found on the ground (i.e . not quarried) that is a suitable size and shape for use as drywall or rubble masonry

(d) Trim: stones cut for specific purposes like:

jambs, sills, copings, cornices, lintels, steps and arch stone (*voussoirs*)



6.9.2 Glass

A. Introduction

- Glass is a transparent or translucent non-crystalline substance made from silica (sand), soda (Na_2CO_3) and lime (CaO or $CaCO_3$).
- When heated glass does not melt at a specific temperature but becomes plastic so that when hot can be moulded by blowing, casting, rolling or extrusion.
- When cooled does not crystallize or solidify at a fixed temperature. Glass is a super cooled mould with a very high viscosity.
- Glass is amorphous; crystalline substances are opaque as light is reflected from grain boundary.
- Molten glass shall be cooled rapidly to ensure amorphous character but not too rapidly to induce thermal stress.
- Pure silica melts at 1700°C, Na_2CO_3 and $CaCO_3$ are added to provide oxides those bring down the melting temperature and thus energy intensive.
- Fe, Mn, Cu, Cr, Co, Ni oxides are added for colour control of glass.

B. Thermal & Optical Properties

- Poor conductor, thickness being low thermal resistance usually is also low and low coefficient of expansion 3.8×10^{-6} per °C.
- By coating or treatment, solar gain factor of glass can be modified.
- Solar gain factor is the ratio of heat admitted to heat incident.
- Idea is to allow as much as visible light possible while filtering the direct sunlight and heat.

C. Strengthened Glass

- Wired glass: wire is sandwiched between molten glass.
- Toughened glass: air glass interface is placed into pre-compression so that inherent flow does not enhance the stress. They are produced by thermal (heated to 600-670°C) or chemical process.

6.9.3 Plastics

Plastics are Classified as:

- **Thermo-plastics** variety softens by heat and hardens when cooled down. It can be used by remolding as many times as required.
- **Thermo-setting plastics** can not be reused .This variety requires a great pressure and momentary heat during moulding which hardens on cooling.

A. Thermo-plastics

- The thermo-plastic or heat non-convertible group is the general term applied to the plastics which becomes soft when heated and hard when cooled.
- Thermoplastic materials can be cooled and heated several times.
- When thermoplastics are heated, they melt to a liquid. They also freeze to a glassy state when cooled enough.
- Thermoplastic can be moulded into any shape.

B. Thermo-setting plastics

- The thermo-setting or heat convertible group is the general term applied to the plastics which become rigid when moulded at suitable pressure and temperature.
- This type of plastic passes originally through thermo-plastic stage. When they are heated in temperature range of 127°C to 177°C, they set permanently and further application of heat does not alter their form or soften them.
- But at the temperature of about 343°C, the charring occurs. This charring is a peculiar characteristic of the organic substances.

C. Based on Physical and Chemical Properties

- **Rigid Plastics:** These plastics have a high modulus of elasticity and they retain their shape under exterior stresses applied at normal or moderately increased temperatures.
- **Semi-rigid Plastics:** These plastics have a medium modulus of elasticity and the elongation under pressure completely disappears, when pressure is removed.
- **Soft Plastics:** These plastics have a low modulus of elasticity and the elongation under pressure disappears slowly, when pressure is removed. Soft plastics are available in a large range of colours, sizes and particularly shapes. They are used in making children's toys e.g: rattles etc., fishing baits.
- **Elastomers:** These plastics are soft and elastic materials with a low modulus of elasticity. They deform considerably under load at room temperature and return to their original shape, when the load is released. The extensions can range upto ten times their original dimensions.

D. Advantages of Plastic

- Corrosion resistance
- Low electrical and thermal conductivity.
- Easily formed into complex shapes, can be formed, casted and joined.
- Wide choice of appearance, colors and transparencies

E. Disadvantages of Plastic

- Low strength
- Low useful temperature range (upto 600°F)
- Less dimensional stability
- Ageing effect, hardens and become brittle over time
- Sensitive to environment, moisture and chemicals

F. Uses of Plastic

- There are more than 10000 different kinds of plastics available in the market and their performance abilities span those of every other known material from soft rubber to steel.
- The typical uses of plastics in building are summarized as follows:
  - Bath and sink units
  - Decorative laminates and mouldings
  - Electrical conduits
  - Electrical Insulators
  - Films for water proofing, damp proofing and concrete curing
  - Floor tiles
  - Foams for thermal insulation
  - Jointless flooring
  - Lighting fixtures
  - Pipes to carry cold water
  - Water resistance adhesives

6.9.4 FRP (Fibre Reinforced Polymer)

A. Introduction

Basically FRP is composed of fibres and matrix.

Fibers Provide strength and stiffness e.g. Carbon, glass, aramid.

Matrix Protects and transfers load between fibers e.g., Polyester, Epoxy, Vinyl Ester, Urethane.

B. Properties of FRP

FRP is Anisotropic:

- High strength in the direction of the fibers
- This anisotropic behavior affects the shear strength, dowel action, and bond performance

FRP does not exhibit yielding (the material is linear elastic until failure):

- Design should account for lack of ductility
- Member does have substantial deformability

C. Composites Features

- Impervious to chloride ion and chemical attack
- Tensile strength is greater that steel
- 1/4th of the weight of steel
- Transparent to magnetic fields and radar frequencies
- Electrically and thermally non-conductive

D. FRP Rebar

These are fibre reinforced bars that can be used at:

- Any concrete member susceptible to corrosion by chloride ions or chemicals
- Any concrete member requiring non-ferrous reinforcement due to Electro-magnetic considerations
- As an alternative to epoxy, galvanized, or stainless steel rebar's
- Where machinery will "consume" the reinforced member i.e., mining and tunneling
- Applications requiring Thermal non-conductivity

6.9.5 Ceramics

- Ceramic is an inorganic, non-metallic solid prepared by the action of heat and subsequent cooling.
- Ceramic materials may have a crystalline or partly crystalline structure, or may be amorphous (e.g., a glass).
- Ceramics now include domestic, industrial and building products and a wide range of ceramic art.

A. Properties

- They are hard and brittle
- Strong in compression
- Weak in shearing and tension
- Withstands chemical erosion due to acidic or caustic environments
- Withstands high temperatures

B. Types of Ceramic Products

Structural:

- These type of ceramics demonstrate enhanced mechanical properties under demanding conditions
- Because they serve as structural members, often being subjected to mechanical loading, they are given the name structural ceramics
- This type of ceramics include bricks, pipes, floor and roof tiles.

Refractories:

- A refractory material is one that can retain its strength at high temperatures
- They are used in linings for furnaces, kilns, incinerators and reactors.
- The oxides of aluminium, silicon and magnesium are the most important materials used in the manufacturing of refractories.

White wares:

- This is a class of products that includes porcelain, china, pottery, stoneware and vitreous tile.
- They are white to off-white in appearance and often contain a significant glossy or vitreous component.
- Imperviousness to fluids, low conductivity to electricity, chemical inertness and an ability to be formed into complex shapes are its properties.

Technical:

- It is also known as engineering, advanced or special ceramics.
- It includes tiles used in space shuttles, missile nose cones, ceramic disk brakes etc.

C. Types of Ceramic Products

Crystalline ceramics:

- These are not amenable to a great range of processing.
- Methods for dealing with them tend to fall into one of two categories:
  Either make the desired shape by reaction in situ, or by forming powders into the desired shape, and then sintering to form a solid body.
- Ceramic forming techniques include shaping by hand, slip casting, tape casting etc

Non-crystalline ceramics:

- Non-crystalline ceramics, being glass tend to be formed from melts. The glass is shaped when in a state of toffee like viscosity.
- Methods like blowing into a mould is used.
- Later heat treatments cause this glass to become partly crystalline and this material is know as glass ceramic which is widely used for cooktops.

D. **Ceramic Products Employed In Building Industry**

Terracotta

- A type of earthenware , is a clay-based unglazed or glazed ceramic, where the fired body is porous.
- Its uses include vessels (notably flower pots), water and waste water pipes, bricks, and surface embellishment in building construction, along with sculpture such as the Terracotta Army and Greek terracotta figurines.

Stoneware

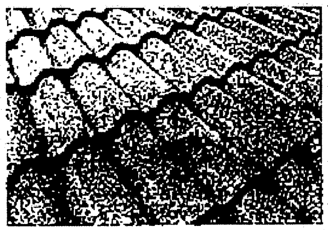
- Stoneware is a vitreous or semi-vitreous ceramic made primarily from stoneware clay or non-refractory fire clay.

Tiles

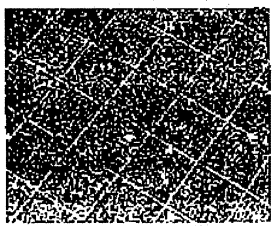
- A tile is a manufactured piece of hard-wearing material such as ceramic, stone, or even glass.
- Tiles are generally used for covering roofs, floors, walls, showers, or other objects such as tabletops.

There are many types of tiles used for residential and commercial applications.

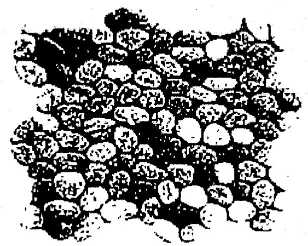
Roof tiles:



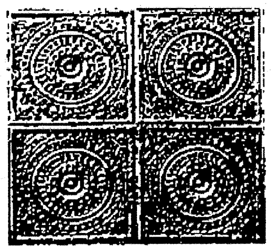
Floor tiles:



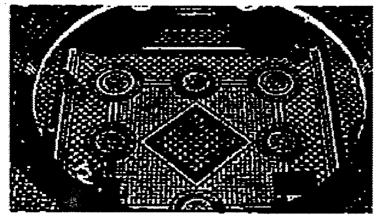
Pebble tiles:



Ceiling tiles:



Wall tiles:



Earthenware

- It is the term for pottery that has not been fired to the point of vitrification and is thus porous.

Porcelain

- Porcelain (also known as china or fine china) is a ceramic material made by heating materials, generally including clay in the form of kaolin, in a kiln to temperatures between 1200 and 1400°C.

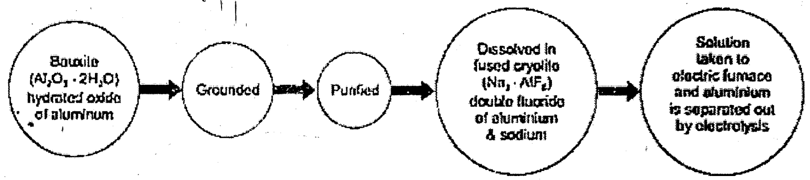
6.9.6 Aluminium

- Aluminium is the 3rd most plentiful element in the earth's crust
- It is present in 8% of the planet's soil and rocks.
- In nature, aluminum is found only in chemical compounds with other elements such as sulphur, silicon, and oxygen.
- Pure, metallic aluminum can be economically produced only from aluminum oxide ore.
- It occurs in all types of clay

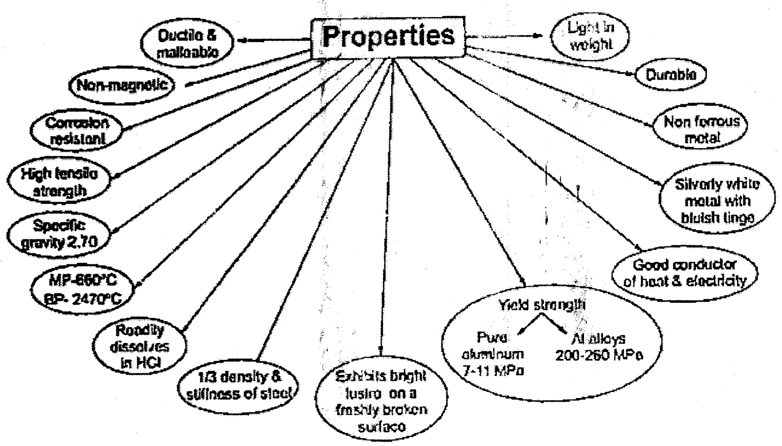
A. **Raw Materials**

- Most useful ore for producing pure aluminum is BAUXITE forms when certain aluminium bearing rocks decompose. It consists of 45-60% aluminum oxide along with various impurities such as sand, iron, and other metals.
- Some deposits are hard rock, most consist of relatively soft dirt that is easily dug from open-pit mines.
- Major producers include Australia, Brazil and Jamaica. Australia produces more than one-third of the world's supply.
- Caustic soda (sodium hydroxide) is used to dissolve the aluminum compounds found in the bauxite, separating them from the impurities
- The largest and most lucrative bauxite deposits are located around the Equator.

B. **Manufacturing**



C. **Properties**



D. **Uses as Building Material**

Air tightness:

- Sealed for dust rainwater etc. when closed
- High functional advantage in air-conditioned buildings

Appearance:

- Smooth bright finish

Strength:

- Tensile strengths of Aluminium alloys is around 70-700 MPa.
- It does not become brittle at low temperatures infact its strength increases.
- At high temperatures, aluminium's strength decreases. At temperatures continuously above 100°C, strength is affected to the extent that the weakening must be taken into account

Weight: Aluminium is light with a density one third that of steel, 2.700 kg/m^3.

Linear expansion: Compared with other metals, aluminium has a relatively large coefficient of linear expansion

Non-magnetic material: Aluminium is a non-magnetic (actually paramagnetic) material. To avoid interference of magnetic fields aluminium is often used in magnet X-ray devices.

6.9.7 Fly Ash

- Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by Electrostatic Precipitator.
- Fly ash is the most widely used pozzolanic material all over the world.
- Comprises of fine particles which rise with the flue gases.
- One of the major pollutants which originate from combustion
- Due to recent mandate of using pollution control equipments, these are now collected using electrostatic precipitators and other particle filters.

Chemical Composition: It is a heterogeneous material containing SiO_2, Al_2O_3 and Fe_2O_3 as major constituents with CaO occasionally being the minor constituent.

A. **Types of Fly ash**

- **Class F:** Fly ash normally produced by burning anthracite or bituminous coal, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only.
- **Class C:** Fly ash normally produced by burning lignite or sub-bituminous coal. Some class C fly ash may have CaO content in excess of 10%. In addition to pozzolanic properties, class C fly ash also possesses cementitious properties.

Uses of fly ash are as follows:

(i) **Admixture for Portland Cement:**

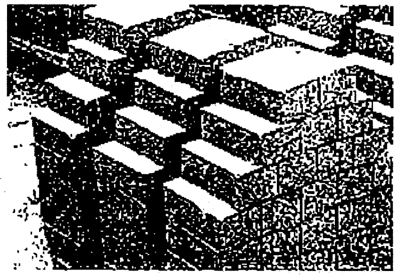
- Fly ash, being primarily pozzolanic, can actually replace a percentage of the Portland cement, to produce an even stronger, more durable and more environment friendly concrete.
- The initial compressive strength is low but as days pass, flyash concrete gains more strength and eventually has a lot more strength as compared to normal Portland cement
- Significantly reduces the release of CO_2 into the atmosphere.
- Can be used for construction of structures on/under water.

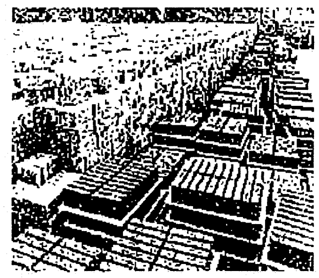
(ii) **Soil Stabilization and modification:**

- Soil stabilization is the alteration of soil properties to improve the engineering performance of soils.
- Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load-bearing capacity of a sub-grade to support pavements and foundations.

(iii) **Flyash Bricks :**

- Fly ash possesses both ceramic as well as pozzolanic properties and therefore can be utilized in a unique way for manufacturing bricks.
- This proves to be very useful for building construction.
- These bricks produced by the new process are superior in quality as they offer higher cold crushing strength and smooth, uniform size.





(iv) Asphalt Concrete:

- Asphalt concrete is a composite material consisting of an asphalt binder and mineral aggregate.
- The hydrophobic nature of fly ash gives pavements better resistance to deterioration caused by water.
- Fly ash has also been shown to increase the stiffness of the asphalt matrix, improving rutting resistance and increasing mix durability.

(v) Embankments:

- Fly ash can be used for construction of road and embankment.
- Saves top soil which otherwise is conventionally used.
- Avoids creation of low lying areas (by excavation of soil to be used for construction of embankments).

(vi) Geopolymers:

- Fly ash has been used as a component in Geopolymers, where the reactivity of the fly ash glasses generates a binder comparable to a hydrated Portland Cement in appearance and properties, but with *possibly* reduced CO_2 emissions.

(vii) As a catalyst:

- Fly ash, mainly class C, may be used in the stabilization/solidification process of hazardous wastes and contaminated soils. For example, the Rhenipal process uses fly ash as an admixture to stabilize sewage sludge and other toxic sludge.

(viii) Waste Treatment:

- Fly ash, in view of its alkalinity and water absorption capacity, may be used in combination with other alkaline materials to transform sewage sludge into organic fertilizer or biofuel.

B. Advantages

As seen above, there are a large number of sectors where flyash can be put into use. There are many reasons for the same like:

(a) In terms of usability in Concrete and Cement:

- Higher Ultimate Strength
- Increased Durability
- Improved Workability
- Reduced Bleeding
- Increased Resistance to Sulfate Attack
- Reduced Shrinkage
- Almost zero emission of greenhouse gases.

(b) In terms of usage as flyash bricks:

- Reduces excavation of clay.
- Low cost of brick as compared to clay brick of same quality.
- Number of bricks required per unit volume of construction is less as dimensional accuracy is maintained.
- Lesser consumption of mortar.
- Better resistance to water damage.

(c) Other benefits of using flyash:

- Reduces soil erosion by replacing top soil as ingredients for most construction mixes.
- Reduces pollution measure by re-use of wastes.
- Reduces the amount of greenhouse gases being added to the atmosphere.
- Hydrophobic nature helps in proper draining off of water from roads and structures.
- Production of crude oil from polyethylene.
- Also used in sewage treatment and generation of biofuel as an alternate source of energy resource.

C. Disadvantages

- Groundwater contamination due to runoffs carrying ill-treated flyash.
- Cannot be used for structures requiring shorter setting time, a demand which is expected by most of the engineers and builders.
- Air content control plays a vital role and can prove crucial for the quality of flyash concrete. Too much reduction in air content can be disastrous.
- It is very difficult to use in winter season due to further increase in already longer setting time.
- Difficult to control colour of cement containing flyash. Hence, a bit problematic to use where cosmetic quality plays a significant role.

D. Conclusion

- Flyash can be proclaimed as one of the most advantageous waste material.
- Using it as a construction material will not only help in its disposal but will also add strength and durability of structures.
- Since, the current usage of flyash in India is still around 25% and below 45% even in the developed countries like United States, there is a huge scope for flyash in upcoming years.

6.9.8 Other Admixtures

The major reasons for using admixtures are:

- To reduce the cost of concrete construction.
- To achieve certain properties in concrete more effectively than by other means.
- To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions.
- To overcome certain emergencies during concreting operations.

A. Important Chemical Admixtures

Plasticizers (water reducers): The organic substances or combinations of organic and inorganic substances, which allow a reduction in water content for the given workability, or give a higher workability at the same water content, are termed as plasticizing admixtures.

The basic products constituting plasticizers are as follows:

- Anionic surfactants such as lignosulphonates and their modifications and derivatives, salts of sulphonates hydrocarbons.
- Non ionic surfactants, such as polyglycol esters, acid of hydroxylated carboxylic acids and their modifications and derivatives.

- Other products, such as carbohydrates etc.
- **Amount used:** Plasticizers are used in the amount of 0.1% to 0.4% by weight of cement.
- **Limitations:** A good plasticizer is one which does not cause air-entrainment in concrete more than 1 or 2%.
- **At constant workability:** The reduction in mixing water is expected to be of the order of 5% to 15%.

NOTE

High degree of workability is required on:

- Thin walls of water retaining structures with high percentage of steel reinforcement
- Deep beams, column and beam junctions
- Tremie concreting
- Pumping of concrete
- Hot weather concreting
- Concrete to be conveyed for considerable distance and in ready mixed concrete industries.

Superplasticities (High range water reducers): Superplasticizers constitute a relatively new category and improved version of plasticizer.

Classification of Superplasticizers:

- Sulphonated malanine-formaldehyde (SMF)
- Sulphonated naphthalene-formaldehyde (SNF)
- Modified lignosulphonates (MLS)

Amount used:

- Based on various types of superplasticizers different amount is used.
- Lignosulphonates – not more than 0.25%
- Carboxylic acids – 0.1%
- Sulphonated malanine-formaldehyde (SMF) – 0.5 to 3%
- Sulphonated naphthalene-formaldehyde (SNF) – 05 to 3%

Results-benefits:

- Permits reduction of water content about 30% without reducing the workability
- It is possible to use w/c ratio as low as 0.25 or even lower and yet to make flowing concrete to obtain strength of order 120 MPa or more.

Retarders: A retarder is an admixture that slows down the chemical process of hydration so that concrete remains plastic and workable for a longer time than concrete without the retarder.

- Retarders are used to overcome the accelerating effect of high temperature on setting properties of concrete in hot weather concreting.
- Very useful when concrete has to be placed in very difficult conditions and delay may occur in transporting and placing.
- Gypsum and Calcium Sulphate are well known retarders.
- Other examples are starches, cellulose products, sugars, acids or salts of acids.

Limitations:

- Retarders should be used in proper amount. Access amount will cause indefinite setting time.
- At normal temperatures addition of sugar 0.05 to 0.10 per cent have little effect on the rate of hydration, but if the quantity is increased to 0.2 percent, hydration can be retarded to such an extent that final set may not take place for 72 hours or more.

Used at:

- Casting and consolidating large number of pours without the formation of cold joints.
- Grouting oil wells, where temperature is about 200°C, at a depth of 6000 meters.

Accelerators: Accelerating admixtures are added to concrete to increase the rate of early strength development.

Why accelerators?

- Permit earlier removal of formwork
- Reduce the required period of curing
- Advance the time that a structure can be placed in service
- Partially compensate for the retarding effect of low temperature during cold weather concreting
- In the emergency repair work.

Commonly used materials as an accelerator:

- Calcium chloride (not used now)
- Silicates fluorosilicates (expensive)

Benefits of Accelerators:

- Accelerators are so powerful that it is possible to make the cement set into stone hard in a matter of five minutes are less.
- With the availability of such powerful accelerator, the under water concreting has become easy.
- Similarly, the repair work that would be carried out to the waterfront structures in the region of tidal variations has become easy.
- The use of such powerful accelerators have facilitated, the basement waterproofing operations.

Air-entraining Admixture:

- One of the important advancements made in concrete technology was the discovery of air entrained concrete.
- Minute spherical bubbles of size ranging from 5 microns to 80 microns distributed evenly in the entire mass of concrete.
- These incorporated millions of non-coalescing air bubbles, which will act as flexible ball bearings and will modify the properties of plastic concrete regarding workability, segregation, bleeding and finishing quality of concrete.
- It also modifies the properties of hardened concrete regarding its resistance to frost action and permeability.

The following types of air entraining agents are used for making air entrained concrete

- Natural wood resins
- Animal and vegetable fats and oils, such as tallow, olive oil and their fatty acids such as stearic and oleic acids.
- Various wetting agents such as alkali salts or sulphated and sulphonated organic compounds.
- Water soluble soaps of resin acids, and animal and vegetable fatty acids.

- Miscellaneous materials such as the sodium salts of petroleum sulphonic acids, hydrogen peroxide and aluminium powder, etc.
- Vinsol resin and Darex are the most important air-entraining agents.

The Effect of Air Entrainment on the Properties of Concrete:

- Increased resistance to freezing and thawing.
- Improvement in workability.
- Reduction in strength.
- Reduces the tendencies of segregation.
- Reduces the bleeding and laitance.
- Decreases the permeability.
- Increases the resistance to chemical attack.
- Permits reduction in sand content.
- Improves place ability, and early finishing.
- Reduces the cement content, cost, and heat of hydration.
- Reduces the unit weight.
- Permits reduction in water content.
- Reduces the alkali-aggregate reaction.
- Reduces the modulus of elasticity.

Damp-proofing & Waterproofing Admixture: In practice one of the most important requirements of concrete is that it must be impervious to water under two conditions;

- Firstly, when subjected to pressure of water on one side.
- Secondly, to the absorption of surface water by capillary action.

Waterproofing admixtures are available in powder, paste or liquid form and may consist of pore filling or water repellent materials.

- Chemically active pore filling materials: silicate of soda, aluminium/zinc sulphates and aluminium/ calcium chloride.
- Chemically inactive filling material: chalk, fullers earth and talc.

Pozzolanic Materials:

- Siliceous or siliceous-aluminous materials.
- Little or no cementitious value,
- In finely divided form and in the presence of moisture,

  Chemically react with calcium hydroxide liberated on hydration, at ordinary temperature, to form compounds, possessing cementitious properties.

Natural Pozzolanas:

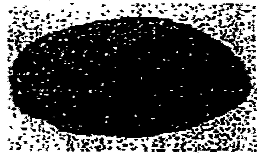
- Clay and Shales
- Diatomaceous Earth
- Opaline Cherts
- Volcanic Tuffs and Pumicites.

Artificial Pozzolanas:

- Fly ash
- Rice Husk ash
- Metakaoline
- Silica Fume
- Blast Furnace Slag
- Surkhi

Silica fume: It is a product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy.

- Micro silica is initially produced as an ultrafine undensified powder
- At least 85% SiO_2 content
- Mean particle size between 0.1 and 0.2 micron
- Minimum specific surface area is 15,000 m^2/kg
- Spherical particle shape



Effect on fresh concrete:

- The increase in water demand of concrete containing microsilica will be about 1% for every 1% of cement substituted.
- lead to lower slump but more cohesive mix.
- make the fresh concrete sticky in nature and hard to handle.
- large reduction in bleeding and concrete with microsilica could be handled and transported without segregation.
- to plastic shrinkage cracking and, therefore, sheet or mat curing should be considered.
- produces more heat of hydration at the initial stage of hydration.
- the total generation of heat will be less than that of reference concrete.

Effect on hardened concrete:

- Modulus of elasticity of microsilica concrete is less.
- Improvement in durability of concrete.
- Resistance against frost damage.
- Addition of silica fume in small quantities actually increases the expansion.

Used for:

- Conserve cement
- Produce ultra high strength concrete of the order of 70 to 120 MPa.
- Increase early strength of fly concrete.
- Control alkali-aggregate reaction.
- Reduce sulfate attack & chloride associated corrosion.

Rice husk ash: Rice husk ash is obtained by:

- Burning rice husk in a controlled manner without causing environmental pollution.
- Material of future as mineral additives.

Amount used:

- 10% by weight of cement.
- It greatly enhances the workability and impermeability of concrete.

Contains:

- Amorphous silica (90% SiO_2) in very high proportion when burnt in controlled manner.
- 5% carbon.
- 2% K_2O.

Effects:

- Reduces susceptible to acid attack and improves resistance to chloride penetration.
- Reduces large pores and porosity resulting very low permeability.
- Reduces the free lime present in the cement paste.
- Decreases the permeability of the system.
- Improves overall resistance to CO_2 attack.
- Enhances resistance to corrosion of steel in concrete.
- Reducing micro cracking and improving freeze-thaw resistance.
- Improves capillary suction and accelerated chloride diffusivity.

Blast furnace slag

- Blast-furnace slag is a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases.
- The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material.
- The granulated material when further ground to less than 45 micron will have specific surface of about 400 to 600 cm^2/ kg (Blaine).

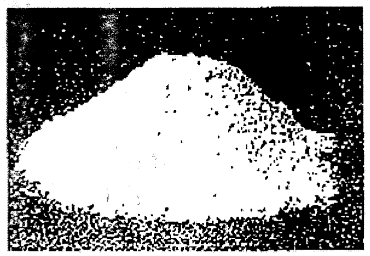
Effects on fresh concrete:

- Reduces the unit water content necessary to obtain the same slump.
- Water used for mixing is not immediately lost, as the surface hydration of slag is slightly slower than that of cement.
- Reduction of bleeding.

Effects on hardened concrete:

- Reduced heat of hydration
- Refinement of pore structures
- Reduced permeabilities to the external agencies
- Increased resistance to chemical attack

Metakaolin:



- Highly reactive metakaolin is made by water processing to remove unreactive impurities to make 100% reactive pozzolan.
- Such a product, white or cream in colour, purified, thermally activated is called High Reactive Metakaolin (HRM).

Effects of Metakaolin:

- High reactive metakaolin shows high pozzolanic reactivity and reduction in $Ca(OH)_2$ even as early as one day.
- The cement paste undergoes distinct densification.
- Densification includes an increase in strength and decrease in permeability.

Use of Metakaolin:

- The high reactive metakaolin is having the potential to compete with silica fume.

Objective Brain Teasers

Q.1 Which of the following is the crudest form of iron?
(a) Wrought iron (b) Cast iron
(c) Pig iron (d) Steel

Q.2 The ultimate tensile strength (in MPa) of mild steel is about
(a) 600 (b) 800
(c) 1200 (d) 1600

Q.3 The ________ is used in the manufacture of rails.
(a) Vanadium steel
(b) Manganese steel
(c) Tungsten steel
(d) Invar steel

Q.4 Melting point of cast iron is about ________ °C.
(a) 1500 (b) 2000
(c) 1800 (d) 1200

Q.5 The most pure form of iron is
(a) Cast iron (b) Steel
(c) Pig iron (d) Wrought iron

Q.6 Nuts and bolts are made of ____________.
(a) Wrought iron (b) Cast iron
(c) Vanadium steel (d) Invar steel

Q.7 Indian Standard rolled steel sections are made of
(a) Pig iron
(b) Manganese steel
(c) Molybdenum steel
(d) Mild steel

Q.8 Which of the following reinforcing bar is most suitable in aggressive environment?
(a) MS bar (b) HYSD bar
(c) TMT bar (d) TMT-HCR bar

Q.9 TOR steel bar is another name given to
(a) MS bar
(b) Cold twisted deformed bar
(c) TMT bar
(d) TMT-HCR bar

Q.10 In plane parts are generally manufactured from
(a) Nickel steel (b) Manganese steel
(c) Vanadium steel (d) Tungsten steel

Q.11 The process of heating the metal followed by gradual cooling to relieve stresses that get developed due to rapid cooling is referred to as ________.
(a) Normalizing (b) Tempering
(c) Annealing (d) Hardening

Q.12 Re-heating of hardened steel below critical temperature to have stable condition in steel is called as ________.
(a) Annealing (b) Normalizing
(c) Hardening (d) Tempering

Q.13 The total impurities in wrought iron are limited to ________ %.
(a) 0.5 (b) 0.15
(c) 1.5 (d) 2

Q.14 High tensile steel is ______ carbon steel.
(a) Low (b) Medium
(c) High (d) Very high

Q.15 Stainless steel contains ________.
(a) Ni (b) Cr
(c) Mn (d) Mo

Q.16 Match List-I (Admixtures) with List-II (Chemicals) and select the correct answer using the codes given below the lists:

List-I
A. Water-reducing admixture
B. Air-entraining agent
C. Superplasticiser
D. Accelerator

List-II
1. Sulphonated melanin formaldehyde
2. Calcium chloride
3. Lignosulphonate
4. Neutralised vinsol resin

Codes:

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

Q.17 Consider the following statements:
The effect of an air entrainment in concrete is to
1. increase resistance to freezing and thawing
2. improve workability
3. decrease strength

Which of these statements is/are correct?
(a) 2 and 3 (b) 1 and 3
(c) 1 alone (d) 1, 2 and 3

Q.18 Assertion (A): The use of fly ash as an admixture in concrete reduces segregation and bleeding.
Reason (R): The use of fly ash as a replacement of sand in a lean-mix increases the workability and has no significant effect on drying shrinkage of concrete.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.19 Why is super plasticizer added to concrete?
1. To reduce the quantity of mixing water.
2. To increase the consistency.
3. To reduce the quantity of cement.
4. To increase resistance to freezing and thawing.

Select the correct answer using the codes given below:
(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 2 and 4 (d) 4 only

Q.20 Consider the following statements:
Admixtures are added to concrete to
1. increase its strength.
2. reduce heat of hydration.
3. delay the setting of cement.
4. reduce water-cement ratio.

Which of these statements is/are correct?
(a) 1 only (b) 1 and 2
(c) 2 and 3 (d) 3 and 4

Q.21 Match List-I (Name of stone) with List-II (Use of stone) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Granite	1. Ornamental work
B. Marble	2. Ballast
C. Chalk	3. Rough stone work
D. Laterite	4. Manufacture of cement

Codes:

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

Q.22 The texture of sandstone is
(a) porphyritic (b) conglomerate
(c) vesicular (d) granular crystalline

Q.23 The crushing strength of a good building stone should be at least
(a) 50 MPa (b) 100 MPa
(c) 150 MPa (d) 200 MPa

Q.24 Assertion (A): Fly ash bricks are used in construction as alternatives to burnt clay bricks.
Reason (R): Fly ash bricks are lighter in weight and are stronger than burnt clay bricks.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.25 Match List-I (Metals or alloys) with List-II (Their common use) and select the correct answer using the codes given below the lists:

List-I
A. Steel bars
B. Zinc
C. Aluminium
D. Brass castings

List-II
1. Water taps
2. Door Frames
3. Reinforcement in concrete
4. Corrugated roof sheet

Codes:

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

Q.26 The coefficient of linear expansion of granite is in the range of that of
(a) glass (b) mild steel
(c) high carbon steel (d) bamboo

Q.27 Polyvinyl chloride (PVC) is a
(a) thermosetting material
(b) thermoplastic material
(c) elasto-plastic material
(d) rigid plastic material

Answers

1. (c)	2. (a)	3. (b)	4. (d)	5. (d)
6. (a)	7. (d)	8. (d)	9. (b)	10. (a)
11. (c)	12. (d)	13. (a)	14. (b)	15. (b)
16. (c)	17. (d)	18. (c)	19. (a)	20. (d)
21. (c)	22. (d)	23. (b)	24. (a)	25. (d)
26. (a)	27. (b)			

Hints & Solution

18. (c)
The fly ash is the residue from the combustion of pulverised coal collected by the mechanical dust collectors or electrostatic precipitators from the fuel gases of thermal power plants. The principal constituents of fly ash are:

SiO_2	:	30-60%
Al_2O_3	:	15-30%
Carbon	:	upto 1-7%
CaO	:	Small
MgO	:	Small
SO_3	:	30%

The fly ash may be used in concrete either as an admixture or in part replacement of cement or fine aggregate.

Use of right quality of fly ash results in reduction of water demand for desired slump. Thus it increases workability. With reduction in water content, bleeding and drying shrinkage will also be reduced.

19. (a)
Superplasticizers, owing to the reduction in w/c ratio, reduce the penetration of chlorides and sulphate into the concrete and, therefore, improve their resistance to the deciding effect of salt or sea water.

20. (d)
Admixtures are essentially classified as water-reducers (plasticizers), set-retarders and accelerators. The purpose of water-reducers is to achieve a higher strength by decreasing the water/cement ratio. Set-retarders are admixtures which delay the setting of concrete. Accelerators accelerate the hardening or the development of early strength of concrete. However, reducing the heat of hydration is not the main purpose of admixtures.

21. (c)
Chalk is used as a colouring material in the manufacture of Portland cement.
Laterite is used as a road metal, in rough masonry work etc.

26. (a)
The linear thermal coefficient range is 6×10^{-6} to 10×10^{-6} for both glass and granite.

27. (b)
Thermoplastic or heat non-convertible group means that the plastics become soft when heated and hard when cooled.
Thermosetting or heat convertible group means that plastics become rigid when moulded at suitable pressure and temperature.
Rigid plastics have a high modulus of elasticity and they retain their shape under external stresses application at normal or moderately increased temperatures.

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