COURSE TITLE – APPLIED CHEMISTRY FOR CIVIL ENGINEERING STREAM

COURSE CODE: BCHEC102/202

MODULE 1- STRUCTURAL MATERIALS

Metals and Alloys: Introduction, Properties and application of Iron and its alloys, Aluminum, and its alloys

Cement: Introduction, composition, properties, classification, manufacturing process of cement, process of setting and hardening of cement, additives for cement and testing of cement

Refractories: Introduction, classification based on chemical composition, properties, and application of refractory materials.

Glass: Introduction, Composition, Types, Preparation of Soda-lime glass, properties, and applications of glass.

Self-learning: Chemistry of reinforced concrete from various sources of water (seawater, groundwater, treated water).

Properties of Iron Metal:

- It is malleable and ductile.
- Iron is ferromagnetic at ordinary temperatures.
- Good conductor of heat and electricity.
- Prone to undergo corrosion due to low electrode potential.

Applications of iron:

- It is used in buildings, bridges, dams, pillars etc.
- Used in machinery tools and equipment.
- Used in transformers, electric motors, engines etc.
- Used in making of steel of various types by alloying with carbon and various metals.

Properties of Heat-Treatable Stainless Steel

- Tough, magnetic and can be worked in cold state.
- They have water and weather resistance.
- corrosion resistance.
- They can be rolled, forged and cold drawn.

Applications:

- Heat treatable stainless steels are used in making surgical instruments, scissors, blades, and cutlery.
- Non heat treatable magnetic type stainless steel is used in making automobile parts and chemical equipment.
- Non heat treatable nonmagnetic type stainless steel are used in making dental and surgical instruments, household utensils, decorative pieces, sinks etc.

Properties of Aluminum

- It is soft, malleable, and ductile.
- Has low density.
- High electrical and thermal conductivity.
- Corrosion resistance is due to the formation of protective oxide layer.

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Applications:

- Used in daily used products like cans, foils, kitchen utensils, window frames airplane parts etc.
- Used in electrical transmission lines.

Properties of Duralumin:

- It has mechanical strength like steel but lightweight with density one-third of stainless steel.
- Good conductor of heat and electricity.
- It is tough, ductile, easily castable and machinable.
- Exhibit very high tensile strength.

Applications of Duralumin

- Used in aircraft, automobile, and locomotive industry.
- Used in surgical instruments.
- It is used as sheet and plate in structural components for aerospace, and military equipment.

Properties and applications of magnalium

- Magnalium alloys with lower magnesium content exhibit greater mechanical strength, greater corrosion resistance and lower density than pure aluminum.
- They are more easily workable and easily weldable than pure aluminum hence they are used in aircrafts, automobile parts, alloys with higher magnesium content are brittle, low corrosion resistance, more reactive and used as metal fuel and also to produce sparks.

Cement

Cement can be defined as a material possessing adhesive and cohesive properties which is capable of bonding materials like stones, bricks, building blocks iron etc.

Composition

1) CaO --- 60- 69% if CaO content is too less the strength of cement will be lesser and may set too quickly and chances of expansion nd cracking is more in such cases.
2) SiO_2 – 17 – 25%, higher SiO_2 will increase the strength of cement but prolongs the setting period.
3) Al_2O_3 ---- 3-8% higher the % of SiO_2 will increase the strength and reduce the setting period.
4) Fe_2O_3 ---- 2- 4%, it imparts strength, hardness and grey colour to the cement.
5) Other constituents: MgO (1-5% So_3(1-3%), $Na_2O + K_2O$ (0.3-1.5%)

Properties of cement:

1) Initial setting time of cement should not be less than 30 minutes and final setting time should not be more than 600 minutes.
2) Compressive strength of cement should not be less than 1.6kg/mm^2 after 3 days. It should not less than 2.2 kg/mm^2 after 7 days.
3) Soundness: this is the measure of volume change in cement in hydration. The smaller the volume change cement is said to be sounder. The volume change of the cement set in 24 hours between 25ºC and 100ºC for unaerated cement should not be more than 10 mm and for aerated cement should not be more than 5 min.
4) Fitness: fitness refers to the particle size of cement. Cement with lesser particle size will have more surface area. Finer the cement particles, the larger will be surface area and cement

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undergoes fast reactions generating large heat resulting in early setting, early development of strength and is likely to develop cracks.

Types of cement

1. Natural cement
2. Pozzolana cement
3. Slag cement
4. Portland cement

Natural cement: natural cement is made by high temperature calcination of naturally occurring limestone such as clay containing Al_2O_3 and SiO_2.natral cement is quick setting and of relatively low strength.

Pozzolana cement: it is made by simple mixing and grinding of slaked lime and volcanic ash which is obtained by rapid cooling of lava which contains silicates of calcium, iron and aluminum.

Slag cement: it is made up of hydrated lime and blast furnace slag (mixture of calcium and aluminum silicates) slag cement sets very slowly and has low strength also poor abrasion resistance. They ae just used in making bulk concrete.

Portland cement: it is a finely ground powder obtained by calcinating together, at about 1500^0C a mixture of argillaceous (clay containing) and calcareous (lime containing) materials in known proportion. It contains compounds of lime, silica, alumina, and iron. All Portland cement is hydraulic in nature as they set and harden under water. It readily forms paste when mixed with water. This paste tends to form a hard mass called concrete. Due to this it's being used everywhere.

Wet Process :

Materials required:

- Source of lime, CaO (limestone, chalk, calcite)
- Source of aluminaAl_2O_3 (clay, slate, shale)
- Source of silica SiO_2 (clay, slate, shale)
- Source of Fe_2O_3 (clay, iron ore)
- Gypsum ($CaSO_4.2H_2O$)

Steps

1. Mixing
2. Burning
3. Grinding

Mixing: in wet process limestone is powdered and stored in separate tank. Alumina, silica source is washed with water to remove organic material and is stored in separate basin. These are sent to grinding mills where they are mixed with water to form a paste called slurry. This slurry contains 38% to 40 % water. This slurry is stored in tanks and kept ready for feeding to a rotary kiln.

Burning: the slurry is taken in a rotary kiln where it is subjected to burning. During burning it undergoes actual chemical changes. Rotary kiln is a long steel cylinder with 30-160 meters and diameter of 2-4 meters. The kiln is kept in slanted position and is rotatable. The upper end is cooler and lower end is hotter. Slurry is passed from upper end and made to flow slowly from upper to lower end with slow rotation.

The following changes takes place based on temperature:

a) The upper part of kiln is called drying zone where the temperature is around 400^0 C, where the water evaporates.
b) The central part is called calcination zone where the temperature is around 1000^0 C, here the limestone is decomposed to quick lime and carbon dioxide.
   $CaCO_3 \longrightarrow CaO + CO_2$

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c) The lower part is called clinkering zone where the temperature is between 1500° C to 1700^0 C. Here lime and clay undergo chemical fusion to form calcium, aluminate, and silicates.

$2CaO + SiO_2 \longrightarrow 2CaO.SiO_2$ (dicalcium silicate)

$3CaO + SiO_2 \longrightarrow 3CaO.SiO_2$ (tricalcium silicate)

$3CaO + Al_2O_3 \longrightarrow 3CaO.Al_2O_3$ (tricalcium aluminate)

$4CaO + Al_2O_3 + Fe_2O_3 \longrightarrow 4CaO.Al_2O_3.Fe_2O_3$ (tetracalcium aluminoferrate)

These fused products are hard greyish stones called clinkers.

Grinding: Cooled clinkers are subjected to grinding by ball milling or tube milling method. 2-3% gypsum is added to prevent the early setting of cement when mixed with water.

Setting and hardening of cement:

When cement is mixed with water to form a paste, it undergoes hydration reactions. Initially, paste is converted into gel and later it is converted into hard mass.

There are two steps in the process of solidification of cement paste:

1) Setting
2) Hardening

1) Setting: in the initial setting of cement paste it is converted into gel. The gel formation is due to the following reactions.

a) Hydration of tricalcium aluminate

$3CaO.Al_2O_3 + 6H_2O \rightarrow 3\ CaO.Al_2O_3.6H_2O$

b) Hydration of tetracalcium aluminoferrate

$4Cao.Al_2O_3.Fe_2O_3 + 7H_2O \rightarrow 3\ CaO.Al_2O_3.6H_2O + CaO.\ Fe_2O_3.H_2O$

Hydration of tricalcium aluminate and tetra calcium aluminoferrate reactions are important as it is responsible for initial setting and early strength of cement.

2) Hardening: the gel formed in the initial setting of cement undergoes crystallization which undergoes crosslinking resulting in hardening of cement.

a) Hydration of tricalcium silicate

The hydration of tricalcium silicate begins within 24 hours and completes in 7 days.

$$2\ [\ 3\ Cao.\ SiO_2] + 6\ H_2O \rightarrow 3\ Cao.2SiO_2.\ 3H_2O + 3\ Ca(OH)_2$$

This reaction is mainly responsible for the development of the strength of cement in the first 7 days.

Dicalcium silicate hydrate between 7 to 28 days.

$$2\ [\ 2\ CaO.SiO_2] + 4\ H_2O \rightarrow 3\ CaO.2SiO_2.6H_2O + Ca(OH)_2$$

Additives for Cement:

Role of accelerators, retarders, extenders, and dispersants in cement.

1) **Accelerators:** these are added to cement to speed up the initial setting time and to start curing earlier. These are very much required in cold conditions where concrete can be frozen before attaining the initial strength. Commonly used accelerators are calcium chloride calcium nitrate, calcium nitrite, calcium formate and aluminum compounds.
2) **Retarders:** these are added to prevent the setting of cement too rapidly. These are used in conditions like high pressure and high temperature like in deep wells. Commonly used retarders are polysaccharides, lignosulphonates, cellulose etc.
3) **Extenders:** these are light weight additives added to reduce the weight of the cement slurry. These have specific gravity lower than that of cement. They decrease density of concrete with acceptable compressive strength. Commonly used extenders are crushed coal, ground rubber, fly ash, sodium silicate.

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4) **Dispersants:** these are added to cement slurries to facilitate blending at high densities without the demand for more water. They improve the flow behaviors of cement slurry and help in pumping of slurry. Commonly used dispersants are poly naphthalene sulphonates and poly melamine sulphonates.

Determination Of Cao by rapid EDTA method

Principle: calcium ions present in the solution of cement is determined by titrating a known volume of the cement solution with standard solution of EDTA. The solution is treated with dimethylamine to maintain the pH at 12-14.4 NaOH is added to precipitate the Mg^{+2} present in the solution as magnesium hydroxide. Glycerol is added to get the sharp end point. Patton and Reeder's indicator is used here.

Procedure:

1) Transfer 25 cm^3 of cement solution into a clean conical flask.
2) Add 5 mL of dimethylamine buffer.
3) Add one test tube full of 4N NaOH.
4) Add 5 cm^3 of glycerol.
5) Add 2 drops of Patton and Reeder's indicator
6) Titrate against the standard EDTA solution taken in the burette.

Calculations:

1 cm^3 of 1M EDTA = 1 millimole of CaO = 56.08×10^{-3} g of CaO

y cm^3 of z M EDTA contains = (0.05608x y x z) g og Cao

0.05608 x y x z g of CaO = weight of CaO in 25.0 cm^3 of cement sample solution.

% og CaO in the cement sample = (weight of Cao in cm^3 / weight of cement in 25cm^3 of solution) x100

Refractories:

Refractories are ceramics materials which can withstand high temperatures with high abrasion and corrosion resistance without undergoing any change in their strength and shape.

They are mainly made up of oxides, carbides, nitrides of silicon, aluminum, magnesium, calcium, boron, chromium and zirconium.

Classification based on Chemical composition.

1) **Acidic refractories** : these refractory materials exhibit high resistance to acidic materials but are readily attacked by basic slags like CaO, MgO etc. these used to handle acidic materials under acidic environments. Silica bricks, fireclay refractories and high alumina refractories are commonly used acidic refrctories.
2) **Basic refractories**: these refractory materials exhibit high resistance to basic materials but are readily attacked by acidic slags like silica, alumina, zirconia etc. these are used to handle basic materials under basic envioronmnet. Magnesite and dolomite refractories are the common types of basic refractories.
3) **Neutral refractories**: These refractories are made from weakly basic/ acidic materials. Silicon carbide, carbon refractories and chromite bricks are commonly used neutral refractories.

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Properties and applications of refractory materials

Properties

1) Refractoriness: It is the measure of ability of a material to withstand heat without undergoing deformation. A good refractory material will withstand very high temperature.
2) **Load-bearing capacity:** refractories must show high load-bearing capacity at higher temperatures.
3) **Dimensional stability:** dimensional stability is the resistance of a material to any change in the volume when it is exposed to high temperature over a prolonged period. Refractories must exhibit high dimensional stability.
4) **Chemical inertness:** the refractories should not react with reactants, slags, gases, fuel ashes, furnace and the products involved inside the furnace. These should be chemically inert.

Applications:

1) **Fire clay refractories** are used in steel manufacturing industries as lining for blast furnaces, ovens and crucible furnace.
2) **Silica bricks** are used in lining roofs of electric furnaces, glass furnace and walls of coke ovens.
3) **Alumina refractories** are used in linings of cement rotary kilns, reheating furnaces.
4) **Silicon carbide refractories** are used in muffle furnace due to their high thermal conductivity. Low thermal coefficient of expansion.

Glass

Glass is an amorphous, hard, brittle transparent material. It is considered a super cooled liquid with very high viscosity.

It is obtained by fusing a mixture of several silicates of metals like Na, K, Ca and Pb.

Types of Glasses.

1. **Soda–Lime glass:** The composition of soda- lime glass is $Na_2O.\ CaO.6SiO_2$ they are low in cost, resistance to devitrification and relatively resistance to water. They melt easily.
2. **Potash- lime glass**: the composition of potash- lime glass $K_2O.CaO.6SiO_2$. it is known as hard glass. They possess high melting points. Fuse with difficulty and are less acted upon acids, alkalis and other solvents. These are costlier than soda lime glasses.
3. **Glass Or Flint Glass:** the composition of lead glass is $K_2O.PbO.6SiO_2$. It is bright and luster. Has a low melting point and is more expensive than lime soda glass. Easier to shape and work with it.

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4. **Borosilicate glass or Pyrex glass or Jena glass:** These are very hard glass. Contains silica and boron with small amount of alumina and some alkali oxides. They have high chemical resistance and low thermal coefficient of expansion.

Preparation of Soda- Lime Glass

Soda-lime glass is the most used glass.

Raw materials:

1. Soda ash (Na_2CO_3) used as source of sodium
2. Limestone (Cao) chalk, lime is used as source of calcium
3. Quartz, white sand used as source of silicon
4. pieces of broken glass (cullet's)used to increase fusibility
5. For imparting colour, various salts are used such as ferric salt for yellow, nickel salts for red, cobalt salts for blue etc.

Steps:

1. **Melting**: raw materials such as sand, soda ash and limestone are taken with proper proportion and mixed with cullets, the mixture is finely powdered and taken in a open hearth furnace maintained at 1800ºC. at this temperature the mixtres melts and fuses.

   $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2 \uparrow$

   $Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2 \uparrow$

   Coloring salts are added at this stage. Heating continues until the molten mas is free from bubbles and glass balls. Then the mixture is cooled to 800º C
2. **Forming and shaping**: molten glass ae subjected to forming and shaping obtain the desired articles. This is done by blowing or molding or pressing between rollers.
3. **Annealing**: the process of cooling glass articles slowly and gradually by passing through different chambers with descending temperatures is called annealing. This is an important step in manufacturing glass. If the glass is cooled rapidly then the outer layer cools down first, leaving the interior side portion in strain. Due to this unequal expansion the article is likely to crack to pieces. The longer the annealing period the better the quality of glass.
4. **Finishing**: All glass articles are subjected to a finishing process after the annealing such as grinding, polishing, cutting and sandblasting

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Properties And Applications of Glasses

Properties of glasses:

- Glasses are amorphous, brittle, transparent solids without definite melting point.
- They can absorb, reflect, and transmit light.
- They are very good electrical insulators.
- They have good chemical resistance and are not affected by air, water, acids and chemical agents except HF which converts its silica into SiF_4.
- They can be formed and moulded into articles.

Applications of Glasses

1. Soda lime glasses are used in window glasses, electrical bulbs, plate glasses, bottles, jars building blocks, table wares etc.
2. Lead glasses are used for high quality table wares, optical lenses, neon sign tubing, cathode ray tubes , electrical insulators and in art objects, in extra dense optical glasses for windows, and I shields to protect personnel from X-rays and gamma-rays in medical and atomic energy fields etc.
3. Borosilicate's glasses are used for pipelines for corrosive liquids, gauge glasses, laboratory apparatus, kitchen wares, chemical plants, television tubes, electrical insulators etc.
4. Silica glasses are used in chemical plants, electrical insulating materials in electrical heaters, furnaces etc.

Question Bank

1. Write the properties and applications of iron and its alloy.
2. Write the properties and applications of aluminum and its alloy.
3. Describe the manufacture of the cement by wet method.
4. Describe the process of setting and hardening of cement.
5. Explain the testing of cement by EDTA method.
6. Define refractories. Mention the properties and applications of refractories materials.
7. Describe the classifications of refractories based on chemical composition.
8. Explain the preparation of soda lime glass. Write the properties and applications of glass.

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