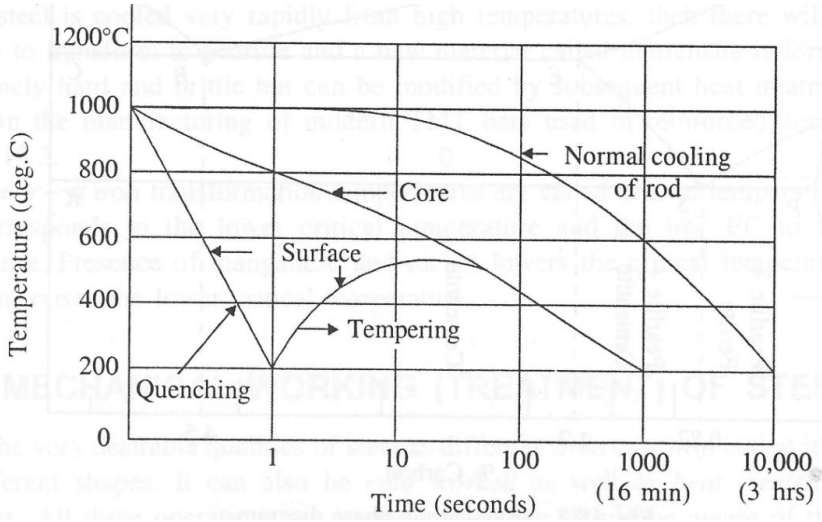
BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI (PILANI CAMPUS)
FIRST SEMESTER 2016 – 2017

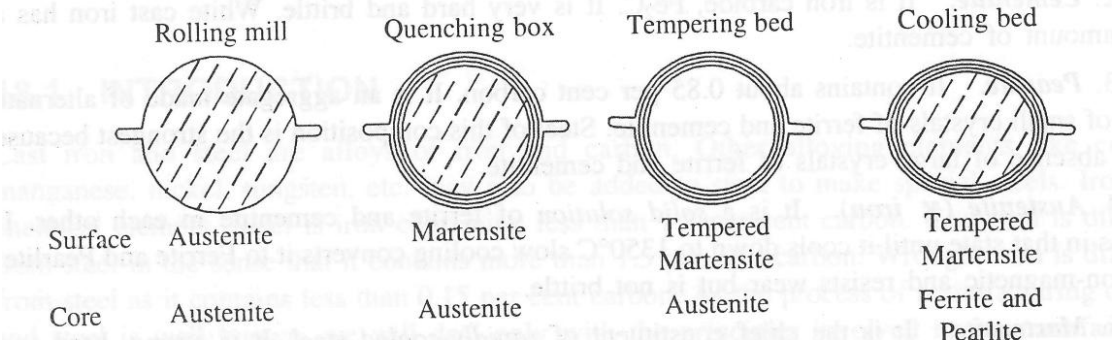
Course: CE G562 Advanced Concrete Technology **Date: 12-12-2016 (2:00 - 5:00 AN)**
Component: Comprehensive Exam (Closed Book) **Max. Marks: 120**

Part C (120 Marks)

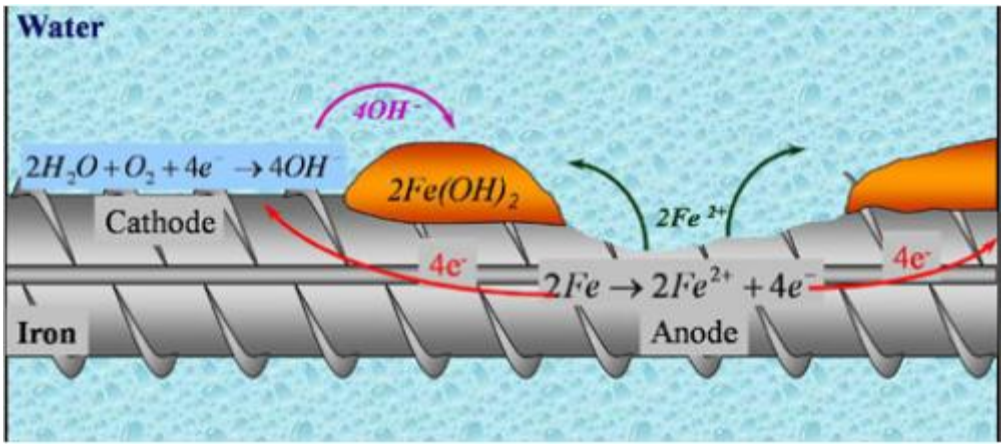
1. Explain the following
   a) What is QST steel? (1)
   Answer: Quenched and Self-Tempered steel. This stands for the kind of reinforcement bars that undergoes rapid cooling after being heated to a critical temperature, thus enhancing its qualities.
   b) Draw and explain the temperature changes on the surface and core of QST steel reinforcement with respect to time (3)
   Answer:



   c) Draw the changes in the structure of surface and core for QST steel (2)
   Answer:



   d) Write down anodic and cathodic reactions in steel reinforcement during corrosion process with a neat sketch (2+2)
   Answer:
   $2Fe \rightarrow 2Fe^{2+} + 4e^-$ (anode)
   $2H_2O + O_2 + 4e^- \rightarrow 4OH^-$ (Cathode)
   $2Fe^{2+} + 4OH^- \rightarrow 2Fe(OH)$ (Cathode)



2. Answer the following

a. You are a site engineer at BITS Pilani renovation project. You are asked to design a concrete with low water-cement ratio and good workability using SNF admixture in concrete. Although mix is correctly designed for minimum slump of 120 mm, trial mixes are found to have workability problems. List the major causes for workability in your view and suggest the solutions (3)

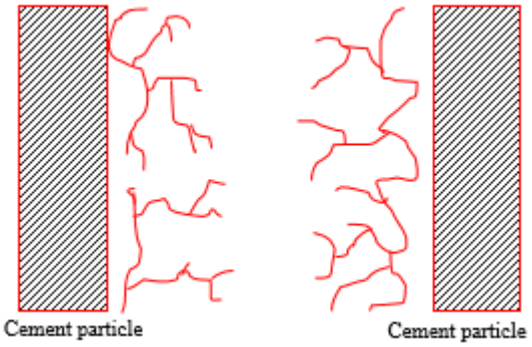
Answer:

(1) SNF works best in tropical hot climates, not in the cold season in Pilani where the temperature goes below 15^{o}C. In this case, PCE or any other 3rd generation SPs are suggested to use.

(2) SNF competes with Gypsum for C3A reaction sites thereby reducing fluidity. In this case, delayed addition of SNF is recommended.

b. Explain: Steric hindrance in the mechanism of SP (2)

Answer: This phenomenon relates to the separation of the admixture molecules from each other due to the bulky side chains. Steric hindrance is a more effective mechanism than electrostatic repulsion. The side chains, primarily of polyethylene oxide extending on the surface of cement particles, migrate in water and the cement particles are dispersed by the steric hindrance of the side chains. (Concrete portal)



c. Explain major factors influence on cement-admixture compatibility in term of characteristics of cement and characteristics of superplasticizer. (3+3)

Answer:

- Type of SP

Degree of retardation varies with type of superplasticizer.
Non-adsorbed SP adversely influences the fluidity of paste
Degree of sulphonation and Presence of sulphonate group at β position significantly affect **SNF**

Presence of low molecular weight fraction and sugar content in the lignosulphonates leads to excessive retardation
Because of condensation of SMF at higher temperature, stability of this admixture is highly affected and leads to incompatibility problem in the warmer countries.

- Dosage of SP
  Beyond an Optimum value, strength decreases.

- Composition of cement
  Higher affinity of SNF based superplasticizer with C_3A is also a key factor affecting its compatibility with cement. Therefore, C3A content in the cement is a main issue to be considered while selecting SP.

- Physical properties of cement
  The fineness of the cement affects the compatibility of the SP.

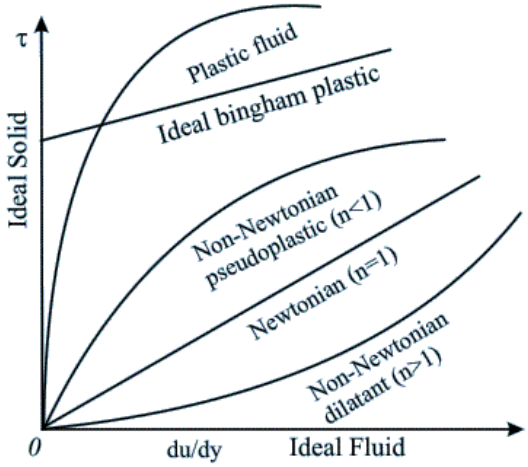
- Mixture proportioning

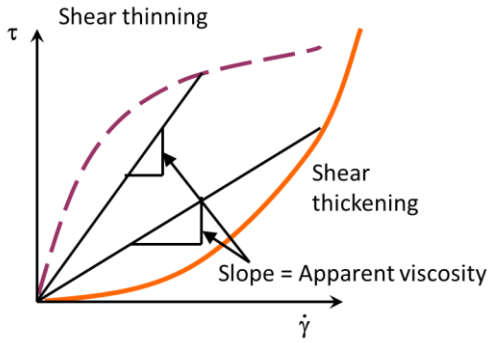
- Batching and mixing

d. List major two test methods used to find optimum dosage of SP (2)
   Answer:
   (1) Marsh Cone test
   (2) Mini-slump test

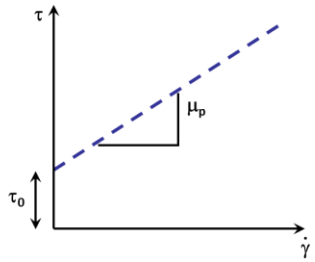
3. Draw individual shear stress and shear strain rate diagram for the following cases (10)
   a. Newtonian liquid
   b. Shear thinning
   c. Yielding + shear-thinning
   d. Bingham
   e. Thixotropy
   f. Non-Thixotropy
   g. Viscosity
   h. Plastic Viscosity
   i. Apparent viscosity
   j. Shear thickening

Answer:





Bingham model



τ_0 = yield (shear) stress

μ_p = plastic viscosity

These are known as the Bingham parameters

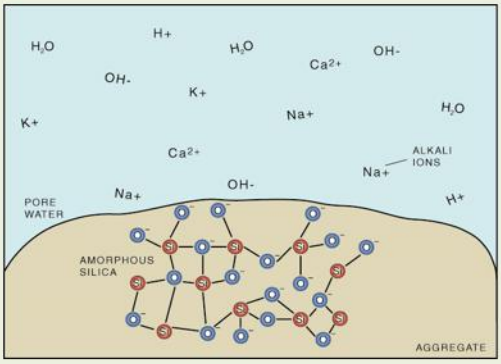
4. Explain the following
   a. What is alkali silica reaction in concrete? (2)

      Answer:

      The alkali–silica reaction (ASR), more commonly known as "concrete cancer", is a reaction which occurs over time in concrete between the highly alkaline cement paste and the reactive non-crystalline (amorphous) silica found in many common aggregates, given sufficient moisture. This reaction causes the expansion of the altered aggregate by the formation of a swelling gel of calcium silicate hydrate (C-S-H). This gel increases in volume with water, and exerts an expansive pressure inside the material, causing spalling and loss of strength of the concrete, finally leading to its failure. (Wikepedia)

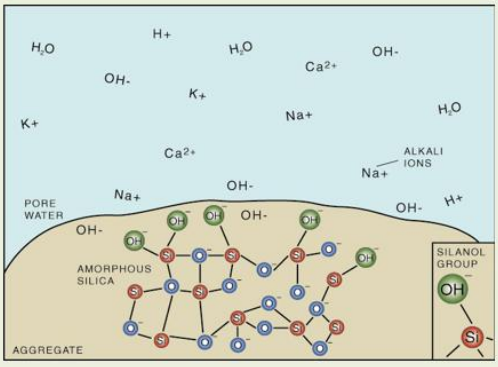
b. Draw step-by-step occurrence of alkali silica reactions in concrete (6)
Answer:

1. Aggregate in solution, pre-ASR damage



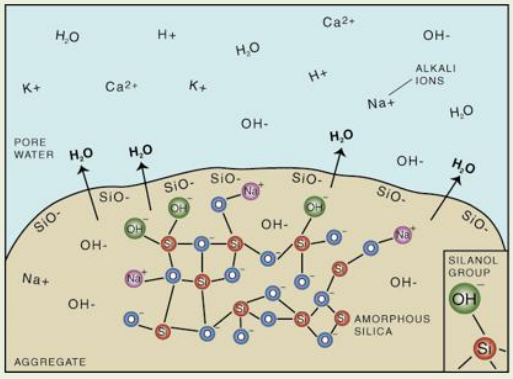
2. Surface of aggregate is attacked by OH^-

$H_2O + Si\text{-}O\text{-}Si \rightarrow Si\text{-}OH\ldots OH\text{-}Si$

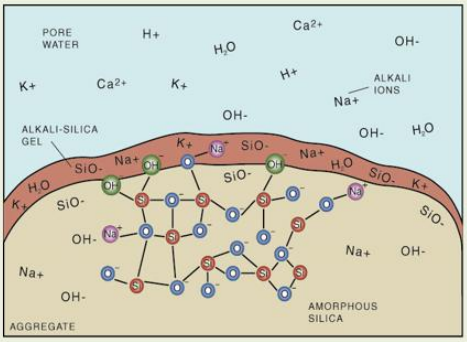


3. Silanol groups (Si-OH) on surface are broken down by OH^- into SiO^- molecules

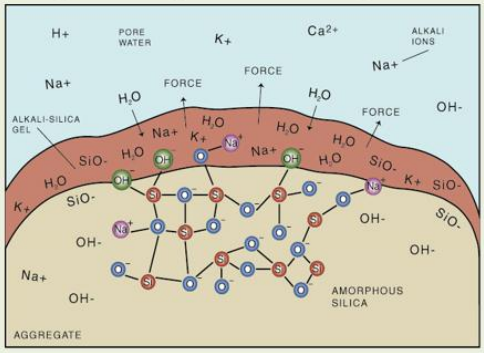
$Si\text{-}OH + OH^- \rightarrow SiO^- + H_2O$



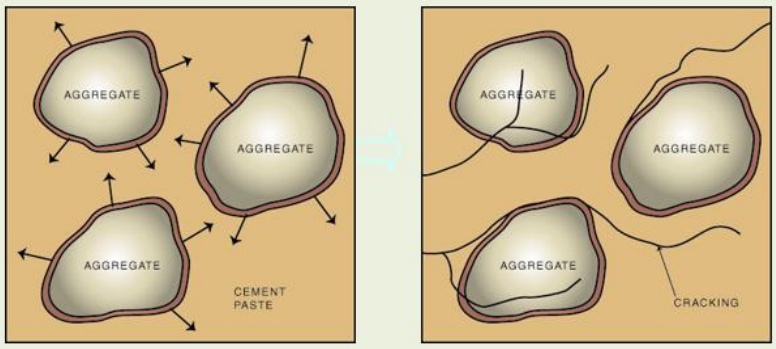
4. Released SiO^- molecules attract alkali cations in pore solution, forming a gel around the aggregate



5. Alkali-silica gel takes in water, expanding and exerting a force against surrounding concrete.



6. When the expansive pressure exceeds the tensile strength of the concrete, the concrete cracks



c. Explain three expansion mechanisms for ASR in concrete (2+2+1)
Answer:

1. Absorption (swelling) theory proposed by Vivian
   "The imbibition of pore water and the resultant swelling of the alkali-silica gel causes expansion. The aggregate grows outward and puts the paste in tension."
2. Osmotic pressure theory proposed by Hansen:

The alkali-silica gel acts as a semi-permeable membrane. Gel allows only an inward diffusion of OH^-, Na^+, K^+, and Ca^{2+} from the pores to the aggregate surface. Thus, the aggregate exerts osmotic pressure against the surrounding paste.

3. Lea modified this theory and stated that there is actually a preferential diffusion of some species – Na+, K+ - over others such as Ca2+.

5. Answer the followings

a. How does alkali activated concrete differ from ordinary Portland cement concrete? (2)
Answer:
(1) Hydration mechanisms are very different. While cement concretes form CSH gel that binds the aggregates, alkali activated binders form a polymer that gives the matrix better strength.
(2) AAC is fire resistant, while concrete is not.
(3) AAC can attain strength at a much higher rate than ordinary concrete.
(4) AAC uses no cement content while OPC concrete uses cement as its binder.

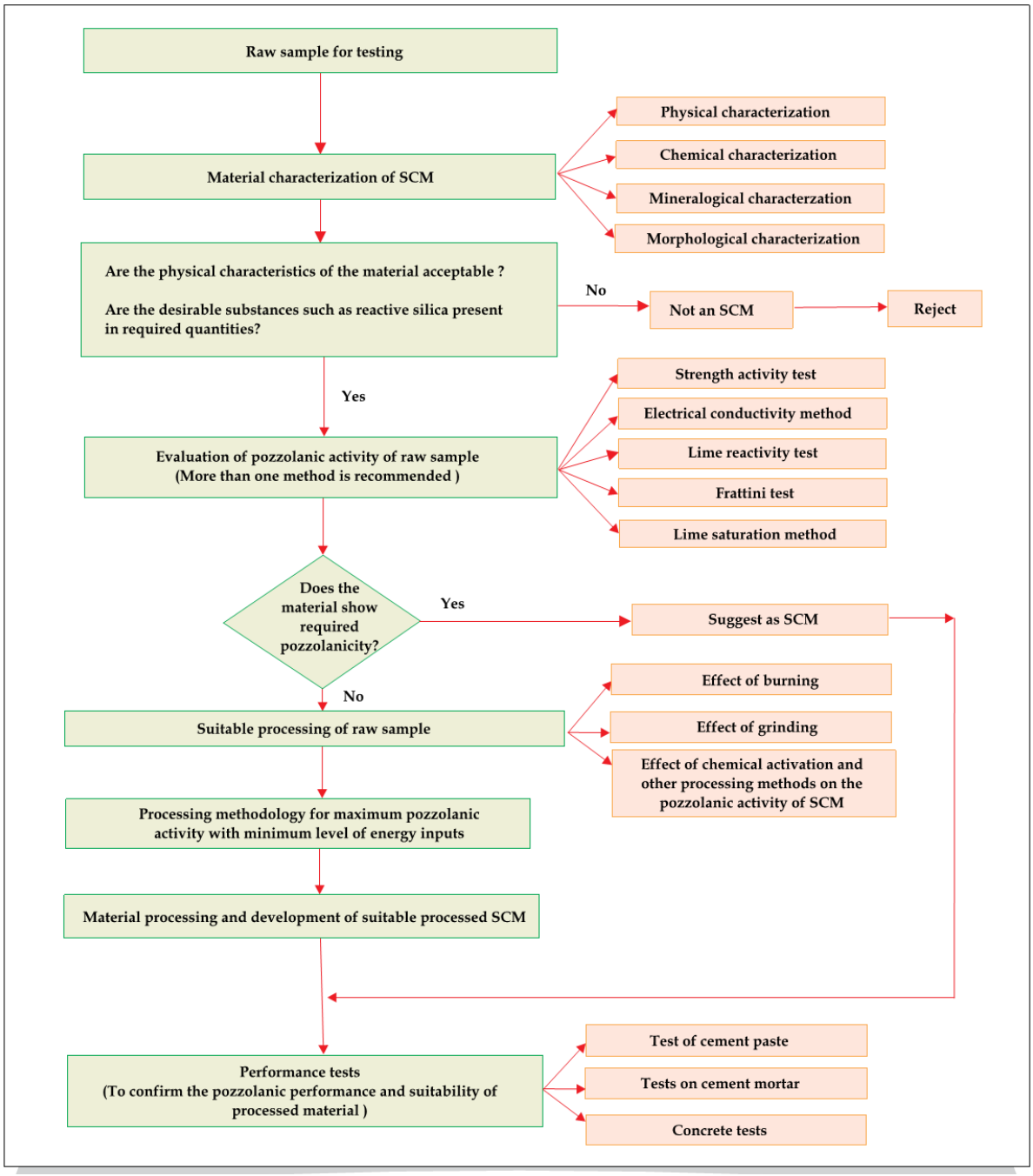
b. Explain different influencing parameters in the performance of alkali activated concrete? (5)

Answer:
- Type of alkali activator
- Dosage of Alkali activator
- Type of source materials
- Curing conditions

c. What is known as activator modulus? (2)
Answer:
Alkali modulus is defined as the ratio of Na_2O to SiO_2 in the alkali activated concrete mix.

d. You are a testing engineer in a geoplymer concrete project. Concrete is used in chlorine rich aggressive environment. To determine permeability of designed geoploymer concrete, you are asked to use any one of the methods (RCPT, Water permeability test). What is your preference and justify your selection (2+1)
Answer:
Preference should be given to Water Permeability Test.
RCPT shall not be used in case of geopolymer since it does not work in highly alkaline conditions. Since alkali activated binders tend to have a high pH, RCPT results may be grossly wrong and unreliable.

6. You have been awarded a construction project in a remote location. Large quantity of concrete is used in construction. To achieve, low heat of hydration and durability, client has instructed to use a pozzolanic material in the mix. Site is far away from thermal plant and steel plant. Moreover, only OPC is available in the adjacent suppliers. However, few waste materials are available in plenty near to your site. If you want to use these materials based on testing as per standard provisions, write down an effective methodology to investigate reactivity and selection of these new materials. (10)

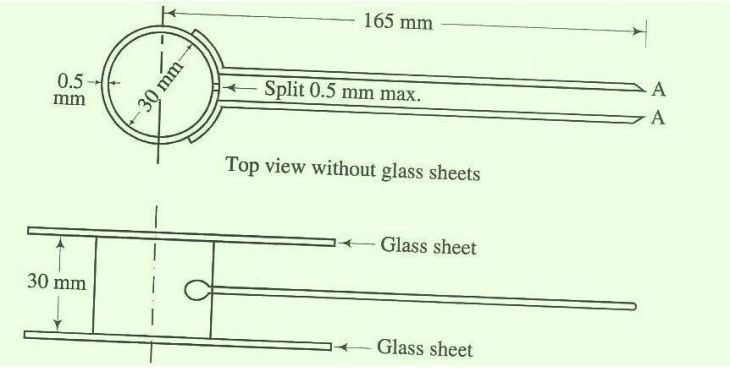


Explain the working principle, instrumentation, application and limitations of any three spectroscopy techniques in details with neat sketches. (3×5=15)

7. Write a short note on testing procedure for the followings
   a. Oxygen permeability test (2)
      Measures the pressure decay of oxygen passed through an oven dried, 30 mm thick slice of a 70mm diameter core placed in a falling head permeameter. The oxygen permeability index is defined as the negative log of the coefficient of permeability
   b. UPV (2)

   c. Cement Soundness test (2)
      Answer:

Soundness Test on Cement is carried out to detect the presence of uncombined lime in cement. This test is performed with the help of Le Chatelier apparatus as shown in figure below. It consists of a brass mould of diameter 30 mm and height 30 mm. There is a split in mould and it does not exceed 0.50 mm. On either side of split, there are two indicators with pointed ends. The thickness of mould cylinder is 0.50 mm.

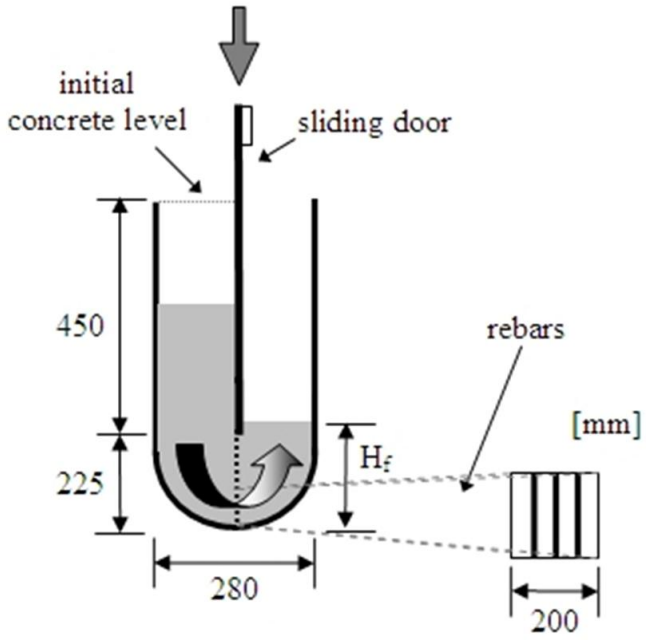


d. Elongation test (2)

Take enough quantity of dry blended sample so that at least 200 pieces of any fraction is present. This is not applicable for the biggest and smallest size. Sieve the blended sample through all the sieves mentioned above starting from the largest sieve. Separate all the individual fractions. Take the entire fraction separately; gauge them one by one through the corresponding slot provided in the gauge. Keep the particles retained by the length separately. The aim should be to retain as much as possible to avoid testing bias. Weigh the particles retained on length gauge. Elongation index is the total weight of the material retained on the various length gauges, expressed as a percentage of the total weight of the sample gauged.

e. Strength activity Index test (for fly ash) (2)
Take a Control specimen with the following proportions.
(Using Ordinary Portland Cement)
Weight of cement =500g
Weight of Graded sand=1375 g
Water=242 ml
Measure the flow value. For the same mix proportion, prepare moulds of PPC with flyash. Water content is to be taken such that the same flow is obtained as for the OPC concrete. Cure both specimens and test for compressive strength after 28 days. The ratio of compressive strength of the opc/flyash mixture to OPC concrete, expressed in percentage, is the Strength Activity Index.

f. U box test (2)



8. Write the followings
   a. List types of cement (2)

      OPC
      PPC
      High alumina cement
      Rapid hardening cement
      Colour cement
      hydrophobic cement
      Sulphate resisting cement
      Low heat cement

   b. List non-destructive techniques used for concrete (2)
      - UPV
      - Borescope
      - Wenner 4 probe resistivity test
      - Chain Dragging
      - Infrared Thermography
      - Profometer/Covermeter
      - Computed Tomography
      - Ultrasonic Tomography

   c. List different types of reinforcements (2)
      <u>Uncoated steel</u>
      - Mild steel ribbed bars
      - High Yield Strength Deformed (HYSD) bars
      - Cold-twisted deformed (CTD) bars (TORsteel)

- Thermomechanically treated (TMT) or Quenched and Self-Tempered (QST) steel
- Stainless steel
- Prestressing steel

Coated steel

- Epoxy coated steel
- Galvanized steel

Fiber-reinforced Polymer (FRP) bars / laminates

d. List durability problems in concrete (2)
   - Acid Attack
   - Carbonation induced corrosion
   - Alkali Silica Reaction
   - Chloride induced Corrosion
   - External Sulphate attack
   - Delayed ettringite formation

9. Explain the following
   a. Action on CH during sulphate attack (2)

      Gypsum formation
      $CH + NS + 2H \rightarrow CSH_2 + NH$
      Gypsum and brucite!
      $CH + MS + 2H \rightarrow CSH_2 + MH$
      Brucite (MH) as a layer *on the surface protects the concrete from further attack only* for a short time and is of no use.

   b. Action on CSH during sulphate attack (4)
      Maximum deterioration occurs with MS

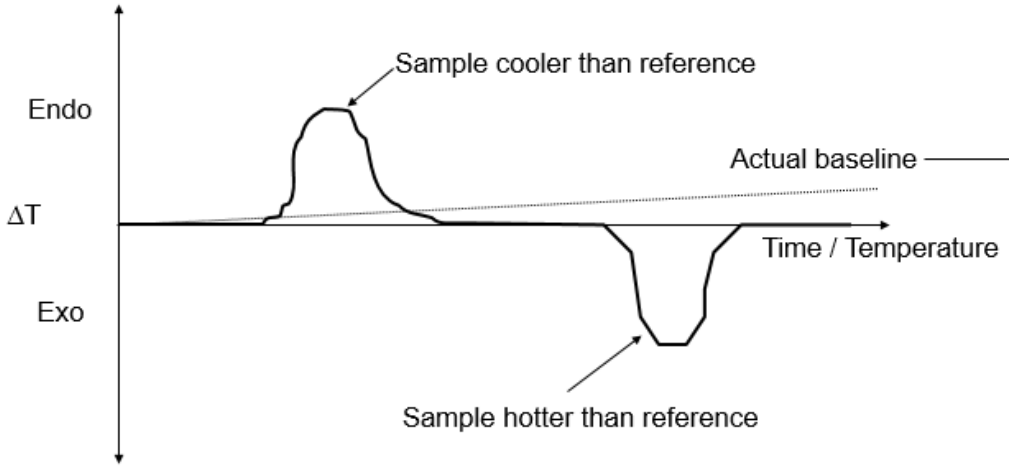
      $C_3S_2Hx + 3MS + (x+21)H \rightarrow 3CSH_2 + 3MH + 3SHy + (12+X-Y)H$

      Process of 'decalcification' It occur whenever the pH reduces (as a result of loss of CH)

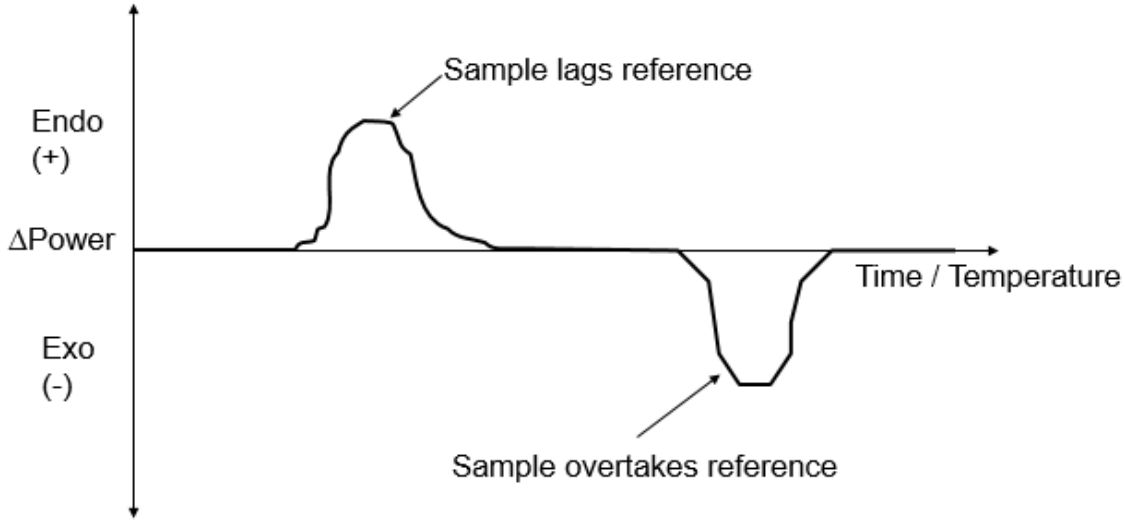
   c. Types of Ettringite (2)
      (a) Primary Ettringite
      (b) Secondary/Later Ettringtite
      (c) Delayed Ettringite

   d. DTA pattern, DSC pattern and TGA pattern (3)

DTA pattern



DSC pattern



TGA Dehydration Pattern

e. Carbonation induced corrosion (2)

Carbon dioxide diffuses into the pores of concrete and reacts with calcium hydroxide; as a result, the alkalinity (pH) of the concrete is reduced. Reduction of pH causes the passivity of reinforcing steel (protective layer) to be destroyed.

Moisture is essential during this process, to convert the CO2 into carbonic acid

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^- CO_2 + 2OH^- \rightarrow CO_3^{2-} + H_2O\ Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$$

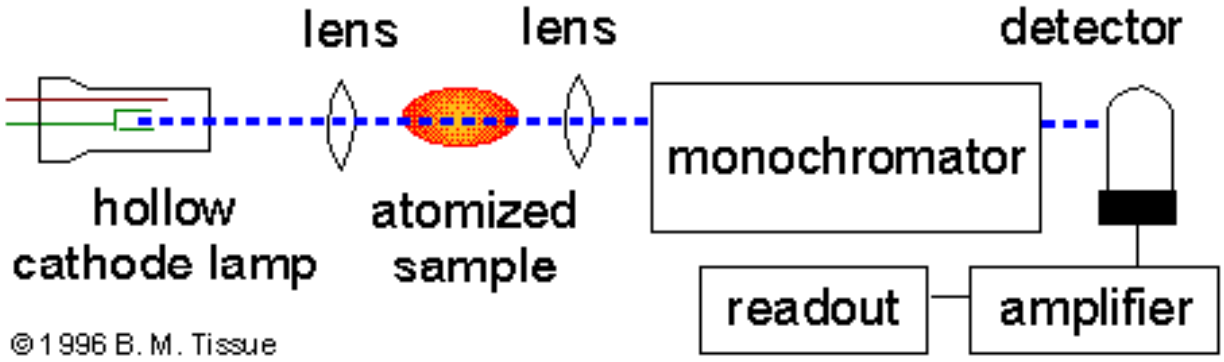
f. Modified Andreassen model (2)

CPFT = ((d-dm) / (D-dm))q

CPFT is the Cumulative (Volume) Percent Finer than,
d is the particle size,
dm is the minimum particle size of the distribution,
D is the maximum particle size, and
q is the distribution coefficient (the exponent)

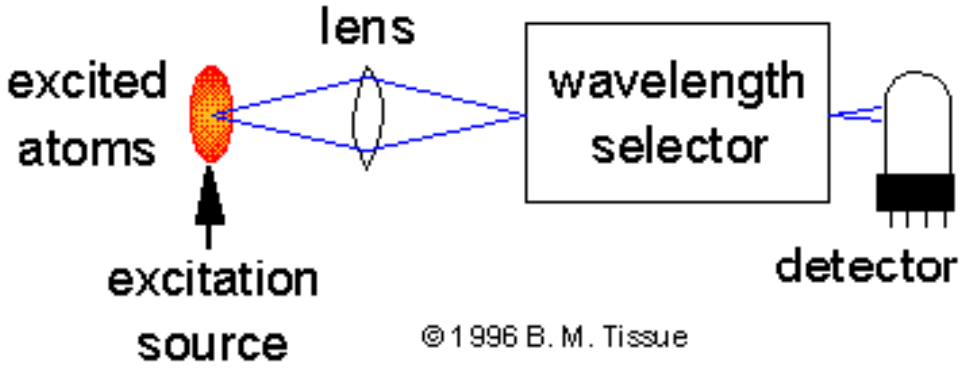
Explain the working principle, instrumentation, application and limitations of any three spectroscopy techniques in details with neat sketches. (3×5=15)

- Atomic Absorption Spectroscopy (AAS)
- Atomic Emission Spectroscopy (AES)
- UV – Visible Light Spectroscopy (UV-Vis)
- Fourier Transform Infra Red Spectroscopy (FTIR)



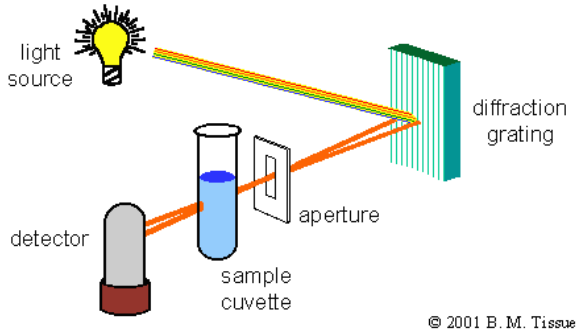
- The analyte concentration is determined from the amount of absorption – using calibration curves
- Applying the Beer-Lambert law directly in AA spectroscopy is difficult due to variations in the atomization efficiency from the sample matrix, and nonuniformity of concentration and path length of analyte atoms (in graphite furnace AA).

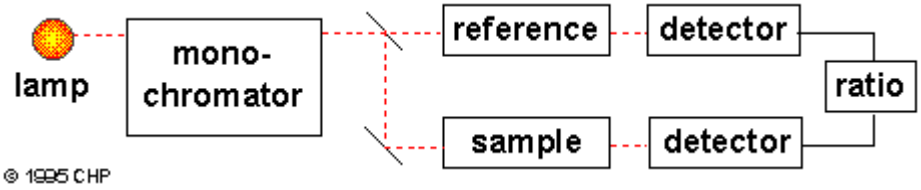
- Uses quantitative
  "measurement of the optical emission from excited atoms to determine analyte concentration".
- Analyte atoms in solution are aspirated into the excitation region where they are desolvated, vaporized, and atomized by a flame, discharge, or plasma.



- The spectra of samples containing many elements can be very congested
- Spectral separation of nearby atomic transitions requires a high-resolution spectrometer.
- Since *all atoms in a sample are excited simultaneously*, they can be detected simultaneously using a *polychromator with multiple detectors.*

- Ultraviolet and visible (UV-Vis) absorption spectroscopy is the "measurement of the
  attenuation of a beam of light
  after it passes through a sample or after reflection from a sample surface"
- Absorption measurements can be at a single wavelength or over an extended spectral range.





Single beam UV Vis spectrometer - instrument is calibrated with a reference cell containing only solvent to determine the I_o value necessary for an absorbance measurement

---