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# Indian Forest Service Main Examination

(2000-2023)

# Civil Engineering

## Paper-II

Topicwise Presentation

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**Civil Engineering : Indian Forest Service Main Examination (Paper-II)**



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# Preface

**B. Singh** (Ex. IES)

Our country has a vast forest cover of near about 25% of geographical area and if man doesn't learn to treat trees with respect, man will become extinct; Death of forest is end of our life. Scientific management and judicial exploitation of forest becomes first task for sustainable development.

Engineer is one such profession which has an inbuilt word "Engineer – skillful arrangement" and hence IFS is one of the most talked about jobs among engineers to contribute their knowledge and skills for the arrangement and management for sustainable development

In order to reach to the estimable position of Divisional Forest Officer (DFO), one needs to take an arduous journey of Indian Forest Service Examination. Focused approach and strong determination are the pre-requisites for this journey. Besides this, a good book also comes in the list of essential commodity of this odyssey.

I feel extremely glad to launch the revised edition of such a book which will not only make Indian Forest Service Examination plain sailing, but also with 100% clarity in concepts.

MADE EASY team has prepared this book with utmost care and thorough study of all previous years' papers of Indian Forest Service Examination. The book aims to provide complete solution to all previous years' questions with accuracy.

On doing a detailed analysis of previous years' Indian Forest Service Examination question papers, it came to light that a good percentage of questions have been asked in Engineering Services, Indian Forest Services and State Services exams. Hence, this book is a one stop shop for all Indian Forest Service Examination, CSE, ESE and other competitive exam aspirants.

I would like to acknowledge efforts of entire MADE EASY team who worked day and night to solve previous years' papers in a limited time frame and I hope this book will prove to be an essential tool to succeed in competitive exams and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

With Best Wishes

**B. Singh**

CMD, MADE EASY Group

Previous Years Solved Papers

# Indian Forest Service Main Examination

# Civil Engineering

## Paper-II

## CONTENTS



# SYLLABUS

## Part-A

### CONSTRUCTION TECHNOLOGY, EQUIPMENT, PLANNING AND MANAGEMENT

1. **Construction Technology :**

   **Engineering Materials:**

   **Physical properties of construction materials :** ***Stones, Bricks and Tiles; Lime, Cement and Surkhi Mortars; Lime Concrete and Cement Concrete, Properties of freshly mixed and hardened concrete, Flooring Tiles, use of ferrocement, fibre-reinforced and polymer concrete, high strength concrete and light weight concrete. Timber : Properties and uses; defects in timber; seasoning and preservation of timber. Plastics, rubber and damp-proofing materials, termite proofing, Materials, for Low cost housing.***

   **Construction :** ***Building components and their functions; Brick masonry : Bonds, jointing. Stone masonry. Design of Brick masonry walls as per I.S. codes, factors of safety, serviceability and strength requirements; plastering, pointing. Types of Floors & Roofs. Ventilators, Repairs in buildings. Functional planning of building : Building orientation, circulation, grouping of areas, privacy concept and design of energy efficient building; provisions of National Building Code. Building estimates and specifications; Cost of works; valuation.***

2. **Construction Equipment :** ***Standard and special types of equipment, Preventive maintenance and repair, factors affecting the selection of equipment, economical life, time and motion study, capital and maintenance cost. Concreting equipments : Weigh batcher, mixer, vibration, batching plant, Concrete pump. Earth-work equipment : Power shovel hoe, bulldozer, dumper, trailors, and tractors, rollers, sheep foot roller.***

3. **Construction Planning and Management :** ***Construction activity, schedules, job layout, bar charts, organization of contracting firms, project control and supervision. Cost reduction measures.***

   **New-work analysis :** ***CPM and PERT analysis, Float Times, cashing of activities, contraction of network for cost optimization, updating, Cost analysis and resource allocation. Elements of Engineering Economics, methods of appraisal, present worth, annual cost, benefit-cost, incremental analysis. Economy of scale and size. Choosing between alternatives including levels of investments. Project profitability.***

## Part-B

### SURVEY AND TRANSPORTATION ENGINEERING

**Survey :** ***Common methods of distance and angle measurements, plane table survey, leveling traverse survey, triangulation survey, corrections, and adjustments, contouring, topographical map. Surveying instruments for above purposes. Tacheometry. Circular and transition curves. Principles of photo-grammetry. Railways: Permanent way, sleepers, rail fastenings, ballast, points and crossings, design of turn outs, stations and yards, turntables, signals, and interlocking, level-crossing. Construction and maintenance of permanent ways : Super-elevation, creep of rail, ruling gradient, track resistance, tractive effort, relaying of track.***

**Highway Engineering :** ***Principles of highway planning, Highway alignments. Geometrical design : Cross section, camber, super-elevation, horizontal and vertical curves. Classification of roads : low cost roads, flexible pavements, rigid pavements. Design of pavements and their construction, evaluation of pavement failure and strengthening.***

**Drainage of roads :** ***Surface and sub-surface drainage.***

**Traffic Engineering :** ***Forecasting techniques origin and destination survey, highway capacity. Channelised and unchannelised intersections, rotary design elements, markings, sign, signals, street lighting; Traffic surveys. Principle of highway financing.***

## Part-C

### HYDROLOGY, WATER RESOURCES AND ENGINEERING

Hydrology : *Hydrological cycle, precipitation, evaporation, transpiration, depression storage, infiltration, overland flow, hydrograph, flood frequency analysis, flood estimation, flood routing through a reservoir, channel flow routing-Muskingam method. Ground water flow : Specific yield, storage coefficient, coefficient of permeability, confined and unconfined aquifers, aquitards, radial flow into a well under confined and unconfined conditions, tube wells, pumping and recuperation tests, ground water potential.*

WATER RESOURCES ENGINEERING : *Ground and surface water resource, single and multipurpose projects, storage capacity of reservoirs, reservoir losses, reservoir sedimentation, economics of water resources projects.*

IRRIGATION ENGINEERING : *Water requirements of crops : consumptive use, quality of water for irrigation, duty and delta, irrigation methods and their efficiencies.*

Canals : *Distribution systems for canal irrigation, canal capacity, canal losses, alignment of main and distributory canals, most efficient section, lined canals, their design, regime theory, critical shear stress, bed load, local and suspended load transport, cost analysis of lined and unlined canals, drainage behind lining.*

Water logging : *causes and control, drainage system design, salinity.*

Canal structures : *Design of cross regulators, head regulators, canal falls, aqueducts, metering flumes and canal outlets.*

Diversion head work : *Principles and design of weirs of permeable and impermeable foundation, Khosla's theory, energy dissipation, stilling basin, sediment excluders.*

Storage works : *Types of dams, design, principles of rigid gravity and earth dams, stability analysis, foundation treatment, joints and galleries, control of seepage.*

Spillways : *Spillway types, crest gates, energy dissipation.*

River training : *Objectives of river training, methods of river training.*

## Part-D

### ENVIRONMENTAL ENGINEERING

Water Supply : *Estimation of surface and subsurface water resources, predicting demand for water, impurities, of water and their significance, physical, chemical and bacteriological analysis, waterborne diseases, standards for potable water.*

Intake of water : *pumping and gravity schemes. Water treatment : principles of coagulation, flocculation and sedimentation; slow-; rapid-, pressure-, filters; chlorination, softening, removal of taste, odour and salinity.*

Water storage and distribution : *storage and balancing reservoirs : types, location and capacity.*

Distribution system : *layout, hydraulics of pipe lines, pipe fittings, valves including check and pressure reducing valves, meters, analysis of distribution systems, leak detection, maintenance of distribution systems, pumping stations and their operations.*

Sewage systems : *Domestic and industrial wastes, storm sewage-separate and combined systems, flow through sewers, design of sewers, sewer appurtenances, manholes, inlets, junctions, siphon. Plumbing in public buildings.*

Sewage characterization : *BOD, COD, solids, dissolved oxygen, nitrogen and TOC. Standards of disposal in normal water course and on land.*

Sewage treatment : *Working principles, units, chambers, sedimentation tanks, trickling filters, oxidation ponds, activated sludge process, septic tank, disposal of sludge, recycling of waste water.*

Solid waste : *collection and disposal in rural and urban contexts, management of long-term ill-effects.*

Environmental pollution : *Sustainable development. Radioactive wastes and disposal. Environmental impact assessment for thermal power plants, mines, river valley projects. Air pollution. Pollution control acts.*

■■■■

# 1 Construction Technology and Equipment

## 1. Cement

1.1 Describe the components, properties and uses of
(i) Air Entraining cement
(ii) Water repellent cement

[5 × 2 = 10 marks : 2000]

Solution:

(i) **Air entraining cement:** Vinsol resin or vegetable fat and oils and fatty acids are ground with ordinary cement. These materials have the property to entrain the air in the form of fine tiny air bubbles in concrete.

**Properties** Minute voids are formed while setting of cement which increase resistance against freezing and scaling action of salts. Air entrainments improves the workability and w/c ratio can be reduced which in turn reduces shrinkage.

**Uses:** Air entraining cements are used in cold areas and improving the workability.

(ii) **Water repellent cement:** The water repellent cement is also called **hydrophobic cement**. A small amount of hydrophobic surfactants such as stearic acid, boric acid or oleic acid is mixed with the ordinary portland cement during grinding of clinker. These substances are added in amount of 0.1% to 0.5% of cement in terms of dry mixtures.

When concrete is being prepared, hydrophobic admixtures plasticize the mix and contribute to the formation of uniformly distributed fines pores in the concrete as it hardness and thus enhance its frost resistance. Hydrophobic cement also features greater water resistance and water impermeability.

The specific surface of cement should not be less than 350 $m^2/g$.

The average compressive strength should not be less than.

72 ± 1 hour $\not<$ 15.69 $N/mm^2$
168 ± 2 hour $\not<$ 21.57 $N/mm^2$
672 ± 4 hour $\not<$ 30.40 $N/mm^2$

**Uses:** It is most suitable for using in basements to make watertight concrete.

1.2 Describe the function properties and uses of:
(i) Rapid Hardening Cement
(ii) Quick Setting Cement

[10 marks : 2001]

Solution:

**Rapid Hardening Cement :** Rapid Hardening Cement has a high lime content and can be obtained by increasing $C_3S$ content but is normally obtained from OPC clinker by fine grinding of 450 $m^2/kg$. The basis of application of rapid hardening cement (RHC) is hardening properties and heat emission rather than setting rate. This permits addition of little more gypsum during manufacture to control the rate of setting. RHC attains same strength in one day which normal OPC achieve in 3 day. Due to low time availability for placing requirement for workability is more. The cost of rapid hardening cement is about 10% more than the ordinary cement. Concrete made with RHC can be safely exposed to frost since it matures more quickly.

**Properties:**

| | |
|---|---|
| Initial setting time | 30 minutes (minimum) |
| Final setting time | 10 hours (maximum) |
| Compressive strength | |
| 1 day | 16.0 N/mm$^2$ |
| 3 day | 27.5 N/mm$^2$ |

**Uses:**

(i) It is suitable for repair of roads and bridges and when load is applied in a short period of time.

(ii) Where formwork is required to removed early.

**Quick Setting Portland Cement:** The quantity of gypsum is reduced and small percentage of **aluminium sulphate** is added. It is ground much finer than OPC.

**Properties:**

Initial setting time = 5 minutes (minimum)

Final setting time = 30 minutes (maximum)

**Use :** It is used when concrete is to be laid under water or in running water.

**1.3 What are various physical properties of a building material? Explain briefly each.**

**[15 marks : 2001]**

**Solution:**

These are the properties required to estimate the quality and condition of the material without any external force. The physical properties of engineering materials are as follows:

| | | |
|---|---|---|
| (i) Bulk density | (ii) Porosity | (iii) Durability |
| (iv) Density | (v) Density Index | (vi) Specific gravity |
| (vi) Fire resistance | (vii) Frost resistance | (viii) Weathering resistance |
| (ix) Spalling resistance | (x) Water absorption | (xi) Water permeability |
| (xii) Hygroscopicity | (xiii) Coefficient of softening | (xiv) Refractoriness |

- **Weathering Resistance:** The property of a material to withstand against all atmospheric actions without losing its strength and shape. Weathering effects the durability of material.
- **Water Absorption :** The capacity of a material to absorb and retain water in it is known as water absorption.
- **Hygroscopicity :** Hygroscopicity is the property of material to absorb water vapour from the air. It depends on the relative humidity, porosity, air temperature etc.
- **Refractoriness :** The property of a material which cannot melt or lose its shape at prolonged exposure to high temperature (1580°C or more).
- **Durability :** The property of material to withstand against the combined action of atmospheric and other factors is known as durability of materials.

**1.4 Name different types of cement and write their special uses.**

**[10 marks : 2002]**

**Solution:**

**(i) Rapid Hardening Cement :** It is suitable for repair of roads and bridges and when load is applied in a short period of time.

**(ii) High Alumina Cement :** It is resistant to action of fire, sea water, acidic water and sulphates and is applied in a short period of time.

(iii) **Super Sulphated Portland Cement :** It is preferred in hydraulic engineering installations and also in constructions intended for service in moist media. This cement is sulphatic resistant.

(iv) **Sulphate Resisting Portland Cement :** It is used as an alternative to order portland cement or PPC or Portland slag cement under normal conditions, and under conditions where there are chances of chemical attack due to sulphates.

(v) **Portland Slag Cement :** Because of its low heat of hydration it can be used for mass concreting e.g. dams, foundations.

(vi) **Low Heat Portland Cement :** It is most suitable for large mass concrete works such as dams, large raft foundations etc.

(vii) **Portland Pozzolana Cement :** It has low heat of evolution and is used in places of mass concrete such as dams and in places of high temperature.

(viii) **Quick Setting cement :** It is used when concrete is to be laid under water or in running water.

(ix) **Masonry Cement :** These cements are used for making terrazoflooring, face plaster of walls (stucco), ornamental works and casting stones.

(x) **Water Repellent Cement :** Water retaining structures like tanks, reservoir, retaining wall, swimming pools, bridge piers etc.

(xi) **Water Proof Cement :** It is used in water retaining structures like tanks, reservoirs retaining walls, swimming pools, bridge piers, etc.

**1.5 Discuss the effect of calcium lignosulphonate and sodium hydroxide admixtures on cement?**

**[5 marks : 2010]**

Solution:

**(a) Effect of Calcium lignosulphonate:**

(i) Calcium lignosulphonate is commonly used dispersing agents which acts as surface active chemicals imparting electrostatic charges on cement particles. This causes cement particles to repel each other and thus prevents coagulation.

(ii) A small amount of air is also entrained in the concrete and workability is increased.

(iii) Decrease the w/c ratio requirement thus increases the strength.

(iv) Reduces the heat of hydration.

**(b) Effect of Sodium hydroxide:**

- Sodium hydroxide is a accelerator used which normally reduces the setting time.
- It accelerates the rate of hydration of cement and consequently the rate of gain of strength.
- It also increase the ability of the concrete to resist frost by speeding up rate of gain of strength.

**1.6 Differentiate flash set and false set?**

**[2 marks : 2015]**

Solution:

**Flash Set :** When portland Clinker is ground alone and mixed with water, the aluminate ($C_3A$) phase initially reacts rapidly and if $C_3A$ level is appreciable, then a so-called flash set or quick set is likely to ensure.

- Since plasticity of mix is not restored after flash setting, it is deleterious to concrete production.
- In order to prevent flash set, gypsum is ground to cement to ensure smooth set regulation prior to normal setting.

**False Set :** False set is sometimes also known as early stiffening or premature stiffening or gum set. It refers to cement which when gauged with water and mixed for short while, stiffens up and appears to set. Remixing breaks up this stiffening and cement proceeds to the normal sets.

**1.7** What are main compounds of cement? Mention their relative behaviour on hydration and rate of strength gain.

[5 marks : 2015]

Solution:

Main compounds of Cement:

(a) **Tricalcium Silicate :** It is supposed to be the best cementing material and is well burnt cement. It renders the clinker easier to grind. It increases the resistance to freezing and thawing, hydrates rapidly generating high beat and develops an early hardness and strength. The hydrolysis of $C_3S$ is mainly responsible for 7 days strength and hardness.

The heat of hydration is 500 J/gram.

(b) **Dicalcium Silicate :** It is about 25-40% of cement. It hydrates and hardens slowly and takes long time to add the strength (after a year or more). It imparts resistance to chemical attack. Raising of $C_2S$ content renders clinker harder to grind, reduces early strength, decreases resistance to freezing and thawing at early stages.

The heat of hydration is 260 J/g.

(c) **Tricalcium Aluminate :** It is a about 5-11% (normally about 10.5%) of cement. It rapidly reacts with water and is responsible for flash set of finely grounded clinker. Tricalcium aluminate is responsible for the initial set, high heat of hydration and has greater tendency to volume changes causing cracking.

The heat of hydration is 865 J/gram.

(d) **Tetracalcium Alumino Ferrite :** It is about 8-14% of cement. It is responsible for flash set but generates less heat. It has poorest cementing value raising the $C_4AF$ content reduces the strength slightly.

The heat of hydration is 420 J/g.

**1.8** What are the approximate oxide composition limits found in ordinary portland cement? Briefly explain the functions of following oxides:

(i) Lime (ii) Silica (iii) Alumina (iv) Iron oxide

[10 marks : 2017]

Solution:

Chemical composition of Portland Cement.

| Oxide | Composition (%) |
|---|---|
| Lime (CaO) | 60 – 65 |
| Silica ($SiO_2$) | 17 – 25 |
| Alumina ($Al_2O_3$) | 3 – 8 |
| Iron Oxide ($Fe_2O_3$) | 0.5 – 6 |
| Magnesia (MgO) | 0.5 – 4 |
| Sulphur Dioxide | 1 – 2 |
| Alkalies (Soda and Potash) | 0.1 – 0.4 |
| Calcium sulphate ($CaSO_4$) | 3% |

Functions:

(i) **Lime (CaO):** It control strength and soundness. It is a major ingredient of cement and constitutes about two-third of cement. Its quantity should be maintained very carefully, as excess quantity and low quantity of lime are both harmful to cement. If it is used in excess quantity, some of lime remains present unused or uncombined or as free lime. Its deficiency reduces strength and setting time.

(ii) **Silica ($SiO_2$):** Its presence in proper quantity forms calcium silicates which gives strength to cement. If silica is used in excess, the setting time of cement is increased and the strength is increased.

(iii) **Alumina ($Al_2O_3$):** It reacts with water very quickly and makes the cement to set quickly. If it is used in excess quantity it will weaken the cement as it acts as flux which lower the clining temperature. But since high temperature is essential for proper cement, it should not be used in excess.

(iv) **Iron Oxide ($Fe_2O_3$):** Iron-oxide imparts colour an hardness to cement. It reacts with lime and silica during manufacture which reduces the calcination temperature. Its presence also imparts strength to the cement.

1.9 Answer the following in brief:

(i) What is the basic advantage of using ferro-cement in ferro-cement concrete?

(ii) Why is carbon fiber reinforced polymer used for seismic retrofitting and repair of damaged structures?

[8 marks : 2018]

Solution:

(i) Advantages of ferro cement in ferro cement concrete.
- High ductility
- Good fire resistance
- High resistance to cracking
- favourable tensile property
- low maintenance cost
- Ability to undergo large deflection
- Improved impact resistance and toughness
- environmental friendly

(ii) Carbon Fiber Reinforced Polymer (CFRP) or Carbon fibre refers to materials consisting of more than 92% by mass of carbon filaments, yarns, roving etc. usually in non graphitic state. It has characteristic like low density, high specific strength and stiffness, excellent chemical stability, biocompatability, low coefficient of thermal expansion and excellent fatigue and creep behaviour. CFRP application in civil engineering includes increasing the load capacity of old structures (such as bridges) which were designed to tolerate lower service loads than they are experiencing today, seismic retrofitting and repair of damaged structures. Seismic retrofitting and repairing of damaged structures using CFRP can be cost effective than replacing the defective structure. CFRP wrapping around sections (columns, beams etc.) can enhance the ductility of the section and greatly increasing the resistance to collapse under seismic loading.

1.10 Briefly explain how fineness modulus of an aggregate is obtained. The actual masses of various materials required at the site to prepare a concrete mix are:

1. Cement = 350 kg/$m^3$
2. Coarse aggregate = 1526 kg/$m^3$

(Fineness modulus = 7.6)

Determine the mass of fine aggregate (having fineness modulus as 2.8) required to make a mix of fine and coarse aggregate having designed fineness modulus as 6.4.

[10 marks : 2020]

Solution:

**Finances modulus**: It is a numerical index of fineness, giving some idea about the mean size of the particles in the aggregate. The fineness modulus (F.M.) varies between 2.0 and 3.5 for fine aggregate, between 5.5 and 8.0 for coarse aggregate and from 3.5 to 15.5 for all in aggregate.

- Aggregate, whose F.M is required, is placed on a standard set of sieves (80, 63, 40, 20, 12.5, 10, 4.75, 2.36, 1.18 mm and 600, 300, 150 μm) and the set vibrated. The material retained on each sieve after sieving represent the fraction of aggregate coarser than the sieve in question but finer than the sieve above. The sum of the cumulative percentage retained on the sieves divided by 100 gives the F.M.

- The object of finding F.M is to grade the given aggregate for the required strength and workability of concrete mix with minimum cement. Higher F.M. aggregate results in harsh concrete mixes and the lower F.M result in uneconomical concrete mixes.

Given, coarse aggregate = 1526 kg/m$^3$; F.M = 7.6

Cement = 350 kg/m$^3$

Fine aggregate = ?; F.M = 2.8,

Desired F.M of mix of fine and coarse aggregate = 6.4

Let quantity of fine aggregate be '$x$' kg/m$^3$.

$$\Rightarrow \quad 6.4 = \frac{\dot{x}\times 2.8+1526\times 7.6}{x+1526}$$

$$6.4x - 2.8x = 1526(7.6-6.4)$$

$$3.6x = 1831.2$$

$$x = 508.67 \text{ kg/m}^3 \simeq 509 \text{ kg/m}^3$$

**1.11 What are the oxide compositions of Ordinary Portland Cement? Mention the typical percentage ranges for each one of them.**

[8 marks : 2021]

**Solution:**

Chemical ingredients of ordinary portland cement are:

**(i) Lime (CaO) : 62-67%**

- This is an important ingredient of cement and its proportion is to be carefully maintained.
- Lime in excess makes the cement unsound and causes the cement to expand and disintegrate.
- Lime in deficiency reduces the strength of cement and causes it to set quickly.

**(ii) Silica ($SiO_2$) : 17-25%**

- Imparts strength to the cement due to formation of dicalcium and tricalcium silicates.
- If it is present in excess, strength of cement increases but setting time gets prolonged.

**(iii) Alumina ($Al_2O_3$) : 3-8%**

- Imparts quick setting property.
- Acts as a flux and lowers clinkering temperature. So, suitable cement type is not formed.
- In excess amount, its presence weakens the cement.

**(iv) Calcium sulphate ($CaSO_4$) : 3-4%**

- Added in the form of gypsum.
- Increases initial setting time of cement.

**(v) Iron Oxide ($Fe_2O_3$) : 3-4%**

- Imparts colour, hardness and strength to cement.

**(vi) Magnesia (MgO) : 0.1-3%**

- Imparts hardness and colour if present in small amount.
- High content causes unsoundness.

**(vii) Alkalies (Soda and Potash; $Na_2O + K_2O$) – (0.5-1.3%)**

- Causes alkali-aggregate reaction, efflorescence and staining.

# 2. Mortar

**2.1 What are requirements of good mortar? How the consistency of mortar is determined?**

**[10 marks : 2001]**

**State the properties of good mortar.**

**[5 marks : 2005]**

**Solution:**

**Requirement of good mortar:**

1. The strength of mortar must be sufficient for development of good bond with building units.
2. ***Mobility and place ability:*** It should be enough workable.
3. It should set quickly to ensure speed of construction.
4. The mortar should be cheap and durable and should not affect the durability of building units in contact.
5. ***Water Retention :*** The mortar should not stratify during transportation and able to retain humidity in thin layer spread over a porous bed.
6. ***Resistance to penetration of rain:*** It should protect the masonry joints and units by forming an impermeable sheet. A satisfactory bond between the building units, mortar and plaster should be ensured.

**Consistency of mortar:** The quantity of water to be added to the mortar should be such that working consistency is obtained. Excess water should be avoided. In case of cement, lime, mortars the following formula may be used to get the approximate quantity of water:

$$V_W = 0.65\,(W_c + W_l) \text{ where}$$

$V_W$ = Volume of water (in litres per $m^3$ of sand)

$W_C$ = added amount of cement kg/$m^3$ of sand

$W_l$ = added amount of lime kg/$m^3$ of sand

In general, the quantity of water depends upon the following factors:

(i) Nature and condition of aggregate

(ii) Temperature and humidity at time of working

(iii) Richness of the mix

The working consistency of the mortal is usually judged by the mason during application to maintain required fluidity.

**2.2 What are different types of lime? Give their composition, source of manufacture, characteristic and use.**

**[10 marks : 2011]**

**Solution:**

According to percentage of calcium oxide and clayey impurities in it, lime can be classified as lean, hydraulic and fatlime.

1. **Lean or Poor lime :** It consists of CaO + MgO <70% with Mgo less than 5% and clayey impurities of more than 30% in form of silica, alumina and iron-oxide. It set on absorbing $CO_2$ from atmosphere.

   **Characteristics:**

   1. Slaking requires more time and so it hydrates slowly. Its expansion is less than that of fatlime.
   2. It makes thin paste with water.
   3. Setting and hardening is very slow.
   4. The colour varies from yellow to grey.

   **Uses:** It gives poor and inferior mortar and is recommended for less important structure.

2. **Hydraulic lime :** It is a product obtained by moderate burning (900°-1100°c) of raw limestone which contains small proportions of clay (silica and alumina) 5-30% and iron oxide in chemical combination with calcium oxide content (CaO + MgO 70-80%) with MgO less than 5%). Depending upon percentage of clay classified as:

| Feebly Hydraulic Lime | Moderately Hydraulic Lime | Eminently Hydraulic Lime |
|---|---|---|
| • (< 5-10% of silica and alumina<br>• slaking time 5-15 min.)<br>• setting time 21 days<br>• Used in damp places | • (<10-20% impurities,<br>• slaking time 1-2 hours)<br>• setting time 7 days<br>• Used in damp places | • (20-30% impurities,<br>• Initial setting time – 2 hours<br>• slakes difficulty<br>• Used in damp places and oil structural purposes |

3. **Pure, Rich or Fat lime :** It is a soft lime (CaO + MgO more than 85% with MgO less than 4%) obtained by calcination of nearly pure limestone, marble, chalk powder, oolitic limestone and calcareous beta. Also known as while washing lime should not have impurities of clay and stone more than 5%. Fat lime is nearly pure calcium oxide and when it is hydrated with the required amount of water the solid lumps fall to a soft fine powder of $Ca(OH)_2$ and high heat of hydration produces a cloud of steam.

**Characteristics:**

1. Slaking is vigorous and the volume becomes 2-3 times.
2. It sets slowly in contact with air and hence not suitable for thick walls or in wet climate.
3. Sp. gravity of pure lime is about 3.4.
4. If kept under water a fat lime waste does not lose its plasticity and consequently does not set and hard.

**Uses:** Fat lime finds extensive use in making mortar, matrix for concrete, base for distemper and in whitewash, manufacturing of cement and metallurgical industry.

## 2.3 Explain characteristics and uses of lime mortar and cement mortar.

[5 marks : 2015]

**Solution:**

**Lime mortar :**

- In this type of mortar lime is used as a binding material.
- It has high plasticity and more workability.
- Good cohesiveness with other building material.
- Shrinkage is less.
- Durability is good but hardens slowly i.e. does not set quickly and hence the progress of work is slow.

**Uses:** It is suitable for masonry and plastering in cheap and light load bearing wall construction above ground level. It is also used in thin joints in brickwork.

**Cement mortar :** Cement mortar is prepared by mixing cement sand and water in desired proportions. It is strongest type of mortar and is therefore preferred for use in construction of structures subjected to heavy loading. Depending upon the strength required, the proportion of cement to sand by volume varies from 1 : 2 to 1 : 6 or more. This mortar can be used where a high strength and water resisting properties is required.

**Uses :** It is used in underground constructions, water saturated soils, and also used in masonry, pointing, plastering, reinforced brickwork and foundation etc.

# 3. Concrete

**3.1 List the various operations in sequence for concreting work and explain only mixing operation.**

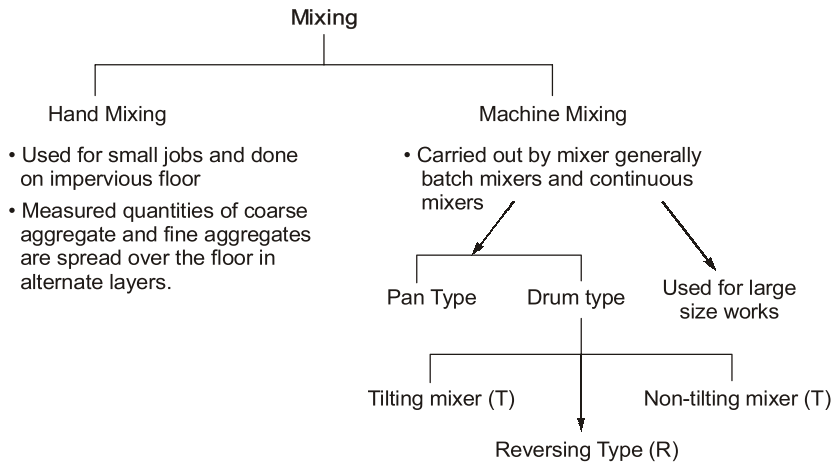
**[10 marks : 2002]**

**Solution:**

The stages of concrete production are:

1. Batching or measurements of materials
2. Mixing
3. Transporting
4. Placing
5. Compacting
6. Curing
7. Finishing

**Mixing :** The object of mixing is to make the concrete mass homogenous and uniform in colour and consistency. All aggregates particles should have coat of cement paste and all the ingredients of the concrete should blend into a uniform mass.




Batchmixers produces properties batch by batch with time interval whereas continuous mixers produces concrete continuously till plant is working.

**3.2 Enumerate the various factors which affect the properties of cement concrete and discuss the effect of w/c on strength of concrete.**

**[10 marks : 2002]**

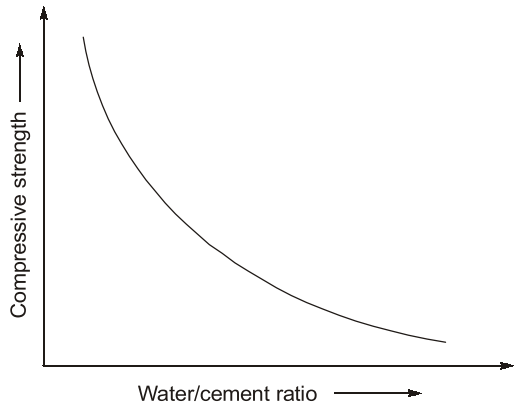
**Solution:**

Factors Influencing strength of concrete:

1. Moisture condition of concrete
2. Air voids percentage
3. Rate of loading
4. Type and Age of cement
5. Cement-Aggregate Ratio
6. Type and size of aggregate
7. Degree of compaction
8. Mixing Time
9. Curing method and Curing Temperature.
10. Design of mix and w/c ratio.
11. Quality of water mixed.

**Water Cement Ratio :** It is defined as the ratio of mass of 'free water' (i.e. excluding that absorbed by the aggregate) to that of cement in a mix is the major factor that controls the strength and many other properties of the concrete.

**Effect of w/c ratio on strength of concrete:** Strength of concrete primarily depends upon the strength of cement paste. The strength of cement paste depends upon the dilution of paste or in other words the strength of paste increases with the cement content and decreases with the air and water content. As per Abrahm's water-cement ratio law, the strength of concrete is mainly dependent on the w/c ratio provided the concrete is workable. The relation between the water/cement ratio and strength of concrete is shown in figure.




It can be seen that lower water/cement ratio could be used when the concrete is vibrated to achieve higher strength whereas comparatively higher strength is required when concrete is to be compacted. In both cases when water-cement is below the practical limit. With increase in w/c ratio and strength of concrete falls due to introduction of void in system (Abraham's law). The graph showing the relationship between strength and w/c ratio is approximately hyperbolic in shape.

### 3.3 Write in brief about Air Entrained concrete an light weight concrete?

[10 marks : 2006]

**Solution:**

**Air Entrained Concrete:** Air entrained concrete contains billions of microscopic cells. These air pockets relieve internal pressure on concrete by providing tiny chambers for water to expand into when it freezes. Air entrained concrete is produced using air in training portland cement, or by introduction of air-entraining agents under careful engineering supervision as the concrete is mixed on the job. The amount of entrained air is usually between four and seven percent of the volume of the concrete but may be varied as required by special conditions.

**Light Weight Concrete :** Light Weight Concrete is most suitable for multi-story buildings. It is desirable to reduce the dead loads. Light weight aggregate concrete is particularly suitable for use where low density, good thermal insulation or fire protection are required but not-all of the available aggregates are equally suitable for any particular application. It is best produced by entraining air in the cement concrete and can be obtained by anyone of the following:

1. By making concrete with cement and coarse aggregate only.
2. By replacing coarse aggregate by porous or cellular aggregate.

The concrete produced is known as cellular concrete which may be classified as:

(a) Foam concrete

(b) Gas concrete

Based on type of grinding material.

The density of LWC varies from 300-1200 kg/m$^3$.

### 3.4 Discuss briefly various effects of adding pozzolana to cement concrete.

[5 marks : 2010]

**Solution:**

**Effect of adding Pozzolana to cement concrete:**

**(a) On Heat of hydration:** The heat of hydration of pozzolana is same as that of low heat cement.

(b) **On strength of concrete:** When pozzolanas are used in addition of an air entraining agent may enable a reduction in the water than if the air entraining agent was added to concrete containing cement only. This may lead to increase in strength and consequently less cement may be permitted for the same strength. At early ages, the replacement of cement by pozzolana usually results in decrease in compressive strength, but the difference becomes less and may disappear at ages of 3 months or more.

(c) **On shrinkage and moisture movement :** It is similar to portland cement i.e., if pozzolana is replacing the cement, then no effect on it.

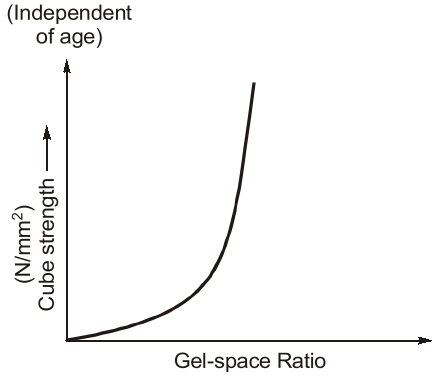
3.5 (i) What is guniting? Mention the uses of guniting in construction Industry.
(ii) What is Get-space Ratio?
(iii) What is Duff-Abraham Law?

[5 + 2.5 + 2.5 marks : 2010]

Solution:

(i) **Guniting :** The gunite may be defined as mortar comprising cement and sand conveyed through an equipment known as gun. It is pneumatically forced on a backing surface, through a nozzle where water is added at a high velocity. The mix leaving the nozzle at high velocity strikes the surface to be repaired or prepared or protected. In the process, the coarser particles rebound from the surface and leave an excellent bond coat of fine grout in intimate contact with backing surface. In the process a thin layer of grout builds up and acts like a cushion reducing the percentage rebound in the successive layers.
The application of mortar or concrete under pneumatic pressure through a cement gun is known as guniting; concrete becomes extremely strong and high bond is achieved.
**Uses:** Gunite can be employed for construction of thin section, e.g. folded plates, shells and thin walls; lining for tunnels and swimming pools; repairing of deteriorated concrete damaged by fire, earthquake, chemicals and in hydraulic structures, strengthening buildings, bridges and jetties, stablizing rocks and earth slopes; protective coatings over prestressing wires and steel pipes and to furnish rough surface texture form architectural point of view. Pneumatic guniting is also used for refractory castables.

(ii) **Gel-space Ratio :** Gel-space ratio is defined as the ratio of volume of hydrated cement paste to the sum of the volumes of the hydrated cement and that of the capillary pores. A typical curve relating gel-space ratio of compressive strength is shown.



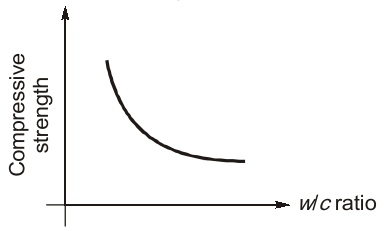

$$S = 240x^3$$

where $S$ = strength of concrete
$x$ = Gel-space ratio

(iii) **Duff Abraham's law :** It states that "For plastic mixtures using neat and clean aggregates, the strength of concrete under specified conditions is governed by the net quantity of water mixed per bog of cement". He gave the following equation to estimate the strength of concrete.

$$S = \frac{A}{B^x}$$

where $S$ = strength of concrete at 28 days
$A$ = 14000 lbs/sqin and $B$ = 7




According to Abraham's law it is evident that strength of concrete mix is inversely related to the mass ratio of water cement, provided the mix is workable.

3.6 (i) What are problems encountered for concreting in hot weather?
(ii) Mention the main components of Portland cement
(iii) What is segregation and bleeding? [3 + 2 + 3 = 8 marks : 2012]

Solution:

(i) **Concreting in hot weather poses some special problems such as,**

- Strength reduction
- Cracking of flat surfaces due too rapid drying.

Concrete that stiffens before consolidation is caused by too rapid setting of cement and too much absorption and evaporation of mixing water. This leads to difficulty in finishing flat surfaces. Therefore, limitations are imposed on placing concrete during hot weather and on the maximum temperature of the concrete; quality and durability suffer when concrete is mixed, placed and cured at high temperature.

(ii) **Main compounds of Cement:**

(a) **Tricalcium Silicate :** It is supposed to be the best cementing material and is well burnt cement. It is about 25-50% of cement. It renders the clinker easier to grind. It increases the resistance to freezing and thawing, hydrates rapidly generating high beat and develops an early hardness and strength. The hydrolysis of $C_3S$ is mainly responsible for 7 days strength and hardness. The heat of hydration is 500 J/gram.

(b) **Dicalcium Silicate :** It is about 25-40% of cement. It hydrates and hardens slowly and takes long time to add the strength (after a year or more). It imparts resistance to chemical attack. Raising of $C_2S$ content renders clinker harder to grind, reduces early strength, decreases resistance to freezing and thawing at early stages.

The heat of hydration is 260 J/g.

(c) **Tricalcium Aluminate :** It is a about 5-11% (normally about 10.5%) of cement. It rapidly reacts with water and is responsible for flash set of finely ground drinker. Tricalcium aluminate is responsible for the initial set, high heat of hydration and has greater tendency to volume changes causing cracking.

The heat of hydration is 865 J/gram.

(d) **Tetracalcium AluminoFerrite :** It is about 8-14% of cement. It is responsible for flash set but generates less heat. It has poorest cementing value raising the $C_4AF$ content reduces the strength slightly the heat of hydration is 420 J/g.

(iii) **Segregation :** It usually implies separation: (a) Coarse aggregate from fine aggregate (b) paste from coarse aggregate or water from the mix and the ingredients of the fresh concrete no longer remain uniformly distributed. It can be reduced by increasing small size coarse aggregates, air entrainment, using dispersing agents and pozzolana.

The causes are : dropping concrete from heights, badly designed mix, concrete carried over long distances-pumping, belt conveyor system, over vibration and during concrete finishing extra floating and tamping.

**Bleeding :** It is defined as the autogenous flow of mixing water within or emergence to the surface from freshly placed concrete is usually to excessive vibration imparted to concrete to achieve full compaction. However well concrete may have been completed, the force of tends to pull the heavy solid particles downward, the lighter water being displaced outward. The upward migration of water known as bleeding ceases either when the solid particles touch each other and cannot settle any more or when the concrete stiffens due to cement hydration and prevents further movement.

Mixes which bleed excessively are those which are harsh and not sufficiently cohesive.

**Methods of checking bleeding:–** It can be checked by;

- Use of uniformly graded aggregate.
- Use of pozzolana-by breaking the continuous water channel.
- By using-entraining agents, finer cements, alkali cement and rich mix.

3.7 What are commonly used chemical admixtures in modern concrete construction? Explain them briefly. [8 marks : 2013]

Solution:

Admixture may be classified as follows:

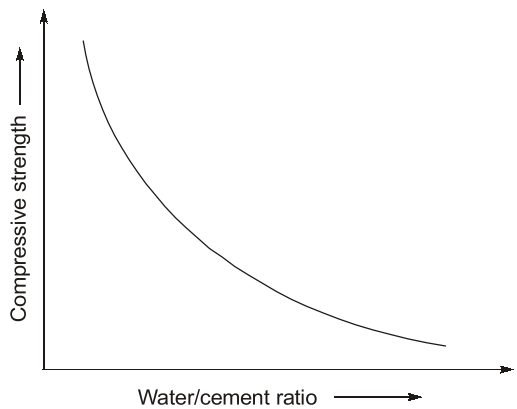
1. **Accelerators :** Normally reduce setting time, accelerate the rate of hydration of cement and consequently the rate of gain strength.
   **Example :** $AlCl_3$, $CaCl_2$, NaCl, NaOH, KOH, Calcium Formate, Formaldehyde etc.
2. **Retarders :** It normally increase the setting time and thus delay the setting of cement. Since these reduce the rate of hydration, more water is available and better is the workability.
   **Example :** Calcium sulphate, sugar, starch, cellulose, ammonium, ferrous and ferric chlorides, etc.
3. **Air Entraining Agents :** Air entrainment increases workability, and resistance of concrete of weathering. The possibility of bleeding and segregation and laitance is also reduced. However there is some loss in the strength of concrete.
   - Surface Active agents
     – Natural wood resins, vinsol resin
     – Darex
     – Animal or vegetable fats
   - Chemicals – Zinc or aluminium powder
   - Dispersing agent – Calcium lignosulphonate
4. **Plasticizers :** Plasticizers are organic or combination of organic and inorganic substances which allow a water reduction for a given workability or give higher workability at same water content. They are surfactants and induce negative charge on individual cement particles.
   **Example :** Carboxylic acids, Calcium lignosulphonates, hydroxy Carboxylic acids etc.
5. **Superplasticizers :** They are hydrodynamic lubricants which impart high workability by reducing friction between the grains or by reducing the amount of water to be added. They are improved version of plasticizers interact both physically and chemically with cement particles. They are anionic in nature and impart negative charge to the cement particles.
   **Examples:** Sulphonated melamine fomaldehyde, napthalene, sulphonated formaldehyde condensates, mixture of succharates and acid amines.

3.8 Define water-cement ratio. Indicate its effect on strength of concrete. [5 marks : 2013]

Solution:

**Water Cement Ratio :** It is defined as the ratio of mass of 'free water' (i.e. excluding that absorbed by the aggregate) to that of cement in a mix is the major factor that controls the strength and many other properties of the concrete.

**Effect of w/c ratio on strength of concrete:** Strength of concrete primarily depends upon the strength of cement paste. The strength of cement paste depends upon the dilution of paste or in other words the strength of paste increases with the cement content and decreases with the air and water content. As per Abrahm's water-cement ratio law, the strength of concrete is mainly dependent on the w/c ratio provided the concrete is workable. The relation between the water/cement ratio and strength of concrete is shown in figure.



It can be seen that lower water/cement ratio could be used when the concrete is vibrated to achieve higher strength whereas comparatively higher strength is required when concrete is to be compacted. In both cases when water-cement is below the practical limit the strength of concrete falls very rapidly due to introduction of air voids. The graph showing the relationship between strength and w/c ratio is approximately hyperbolic in shape.

**3.9 State the important properties of concrete which govern the design of concrete mix. Explain them in brief.**

**[5 marks : 2014]**

Solution:

**Important properties of concrete governing design of concrete mix:**

(i) *Grade of Concrete :* The grade M20, 25 connotes the characteristic strength, $f_{ck}$ of 20 N/mm$^2$, 25 Nmm$^2$ respectively and $\sigma$ based on degree of control to be exercised on site.

(ii) *Type of cement:* The grade of OPC such as 33, 43 or 53 grade PPC to relevant specification.

(iii) *Type and size of aggregate :* Natural sand, crushed stone, gravel etc. conforming to IS : 383-1970 quoting source of supply.

(vi) *Nominal maximum size of aggregate:* 40, 20 mm, 10 mm as per IS383-1970.

(v) *Type of mixing and curing water :* This is required for durability consideration.

(vi) *Maximum free water/cement ratio by weight :* Whether fresh potable water, seawater, ground water to be used.

(vii) *Degree of workability :* This is dependent on placing and compaction condition.

(viii) *Air content and type of admixture :* This is inclusive of entrained air.

(ix) *Maximum/minimum density of concrete :* These are considered in design of concrete mix.

(x) Maximum/minimum temperature of fresh concrete.

**3.10 What is Fibre Reinforced Concrete? What are applications of FRC? Mention the classification of fibres on Geometry?**

**[10 marks : 2015]**

Solution:

**(i)** Fibre reinforced concrete can be defined as composite material consisting of mixture of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres.

Following are different types of fibres used in construction industries:

(a) Steel fibre reinforced concrete
(b) Polypropylene fibre reinforced (PFR) cement mortar
(c) Glass fibres
(d) Asbestos fibres
(e) Carbon fibres
(f) Organic fibres

**(ii) Applications of FRC:**

1. Used in shotcrete and also can be used in normal concrete.
2. Used for on-ground floors and pavements.
3. Glass FRC used in facing panels, piping for sanitation network systems and decorative non-recoverable framework.
4. Asbestos fibres are suitable for making sheet product piles, tiles and corrugated roofing elements.

**(iii) Classification based on geometry:** Unidirectional, Bi-directional and Hybrid (Mix of both).

**3.11 (i) What is curing of concrete? Explain the advantages of autoclaving.**
**(ii) What is bleeding of concrete? How can it be avoided?**

**[5 + 5 = 10 marks : 2015]**

Solution:

(i) **Curing of Concrete :** The process of keeping concrete damp for making sufficient water available to concrete to allow it to gain full strength is known as curing. The object is to prevent loss of moisture or heat and moisture to accelerate the gain of strength. Curing must be done at least three weeks and is no case for less than 10 days.

**Methods of Curing :** are as follows:

1. Water Curing
2. Steam Curing
3. Curing by Infrared Radiation
4. Electrical Curing
5. Chemical Curing

The benefits of autoclaving usually at 180°C arise from a rapid pozzolanic reaction between portland cement and often added lime with very fine siliceous sand or fly ash or mixture of two material. Autoclaving results in early gain of strength and good resistance to freezing and thawing is developed.

(ii) **Bleeding :** It is defined as the autogenous flow of mixing water within or emergence to the surface from freshly placed concrete is usually due to excessive vibration imparted to concrete to achieve full compaction. However well concrete may have been completed, the force of tends to pull the heavy solid particles downward, the lighter water being displaced outward. The upward migration of water known as bleeding ceases either when the solid particles touch each other and cannot settle any more or when the concrete stiffens due to cement hydration and prevents further movement.

Mixes which bleed excessively are those which are harsh and not sufficiency cohesive.

**Methods of checking bleeding :** It can be checked by;

- Use of uniformly graded aggregate
- Use of puzzolana – by breaking the continuous water channel.
- By using – entraining agents, finer cements, alkali cement and rich mix.

3.12 **Define workability. What is the effect of following on workability of concrete : size of aggregate, cement content, shape of aggregate, Grading of Concrete?**

**[5 marks : 2015]**

Solution:

(i) **Workability :** Workability is defined as the property of concrete which determines the amount of usual internal work necessary to produce full compaction. It can also be defined as the ease with which concrete can be compacted 100% with regard to mode of compaction and place of deposition.

Workability is different than consistency. The latter indicates degree of fluidity or mobility.

(ii) **(a) Size of aggregate :** For big aggregate size, the total surface area to be wetted is less, also less paste is required for lubricating the surface to reduce internal friction. For a given water content big size aggregate give high workability.

**(b) Cement content :** Cement content influences the workability to a large extent. The higher the cement content, less leaner will be the concrete.

**(c) Shape of aggregate :** For a given water content, round and cubical shape of aggregates are more workable than rough, angular or flaky aggregate because the former type of aggregates requires less cement paste for lubrication as these have less surface area and lesser voids. In case of round aggregates frictional resistance is also small so less lubrication is required. For this reason river sand and gravel provide greater workability than crushed sand and aggregates.

**(d) Grading of aggregate :** Property graded aggregates are more workable. It is so because such a mix will have least voids and thus excess cement paste will be available as lubricant. This also prevents segregation.

3.13 (i) What is workability of concrete?

(ii) What is the effect of the following on the workability of fresh concrete?

(a) Size of aggregate (b) Cement content

(c) Water to cement ratio (d) Entrained Air

[5 + 2 × 4 = 13 marks : 2015]

Solution:

(i) **Workability :** Workability is defined as the property of concrete which determines the amount of useful internal work necessary to produce full compaction. It can also be defined as the ease with which concrete can be compacted 100% with regard to mode of compaction and place of deposition.

Workability is different than consistency. The latter indicates degree of fluidity or mobility.

(ii) **(a) Size of aggregate :** For big aggregate size, the total surface area to be wetted is less, also less paste is required for lubricating the surface to reduce internal friction. For a given water content big size aggregate give high workability.

**(b) Cement content :** Cement content influences the workability to a large extent. The higher the cement content, less leaner will be the concrete i.e., less workable.

**(c) Water cement ratio :** The fluidity of concrete increase with water cement ratio. At side, normal practice is to increase the water cement ratio to make the concrete workable which lowers strength.

**(d) Air Entraining Agents :** Air entrainment increases workability, and resistance of concrete of weathering. The possibility of bleeding and segregation and laitance is also reduced. However there is some loss in the strength of concrete.

3.14 List out different quality tests to be done for

(i) Cement (ii) Fine aggregate

(iii) Coarse aggregate (iv) Fresh concrete

(v) Hardened concrete

[2 × 5 = 10 marks : 2015]

Solution:

(i) Cement Tests :

- Physical test (Air Permeability method)
  - (a) Fineness test
  - (b) Initial and Final setting – Vicat apparatus method
  - (c) Consistency test
  - (d) Soundness test – Lechatelier method, Autoclave
- Chemical Test
  - (a) Loss on ignition

(ii) and (iii) Find Aggregate and Course Aggregate:

(a) Particle size distribution test

(b) Flakiness Index and Elongation Index test

(c) Deleterious Materials and Organic impurities test

(d) Specific Gravity and Water absorption test

(e) Bulking test (For fine aggregate only)

(f) Crushing value test

(g) Ten percent fine test

(h) Aggregate Impact value test

(i) Aggregate Abrasion value (For coarse aggregate only)

(j) Soundness test (For fine aggregate only)

(iv) Fresh Concrete:

(a) Workability test – Slump test, compaction-factor test.

(v) Hardened Concrete:

(a) Compression test (b) Flexure test (c) Split tensile strength test

**3.15 What do you understand by the term "segregation" of concrete? What are the common causes of segregation ? What are the methods of prevention of segregation? How bleeding is different from segregation? What are the causes and how it can be prevented?**

**[15 marks : 2017]**

Solution:

**(a) Segregation:** It usually implies separation: (a) coarse aggregate from fine aggregate (b) paste from coarse aggregate or water from the mix and the ingredients of the fresh concrete no longer remain uniformly distributed.

**Prevention:** It can be reduced by increasing small size coarse aggregates, air entrainment, using dispersing agents and pozzolana.

**Causes:** The causes are : dropping concrete from heights, badly designed mix, concrete carried over long distances-pumping, belt conveyor system, over vibration and during concrete finishing extra floating and tamping.

**(b) Bleeding:** It is defined as the autogenous flow of mixing water within or emergence to the surface from freshly placed concrete is usually due to excessive vibration imparted to concrete to achieve full compaction. However compaction of concrete may have been completed, the force of tends to pull the heavy solid particles downward, the lighter water being displaced outward. The upward migration of water known as bleeding ceases either when the solid particles touch each other and cannot settle any more or when the concrete stiffens due to cement hydration and prevents further movement.

Mixes which bleed excessively are those which are harsh and not sufficiently cohesive.

**Methods of checking bleeding:–** It can be checked by;

- Use of uniformly graded aggregate.
- Use of pozzolana-by breaking the continuous water channel.
- By using-entraining agents, finer cements, alkali cement and rich mix.

**3.16 Which properties of normal concrete will improve by adding polymers in a polymer concrete? What are the worthwhile applications of costly polymer concrete?**

**[8 marks : 2020]**

Solution:

Polymer concrete is a composite wherein the polymer replaces the cement-water matrix in the cement concrete. It is manufactured in a manner similar to that of cement concrete. Monomers or pre-polymers are added to the graded aggregate and the mixture is thoroughly mixed by hand or machine. The impregnation of monomer and subsequent polymerization reduces the inherent porosity of the concrete. Polymers–polyvinyl acetate, homopolymer emulsions and vinyl acetate copolymer emulsions– are added to increase strength, resistance to oil, grease and abrasion. They also improve bond between new and old concrete and are useful for prefabricated structural elements and prestressed concrete. It is most suitable for structures with a high ratio of live load to dead load and composite construction.

**Applications**: Polymer concrete finds its applications in the production of prefabricated elements, prestressed concrete, ferrocement products, marine works, nuclear power plants and industrial applications. Because of its high sulphate and acid resistance properties it is most suitable for sewage disposal works.

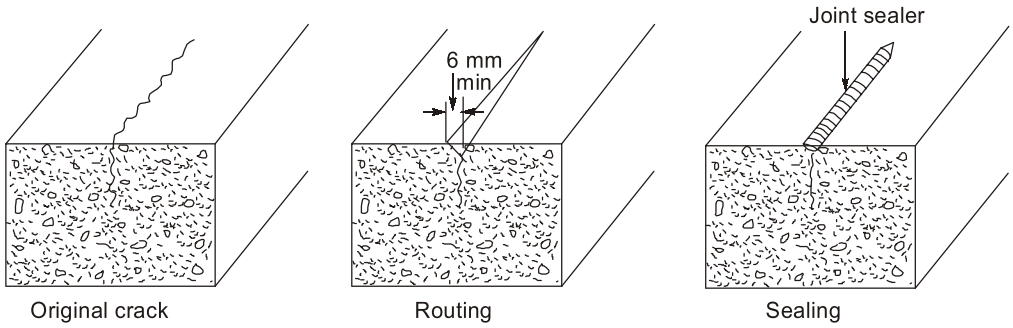
3.17 Briefly discuss the following techniques to repair various types of cracks in concrete surface:
1. Routing and sealing
2. Stitching
3. Grouting

[5 × 3 = 15 marks : 2020]

Solution:

1. **Routing and Sealing :** The crack or joint sealers are very important in concrete structures as every concrete structure has cracks or joints. The crack sealers should ensure the structural integrity and serviceability. In addition they provide protection from the ingress of harmful liquids and gases.

   The method consists of enlarging the crack along its length on the exposed surface (called chasing or routing) and sealing it with a suitable joint sealant as illustrated in figure. Omission of routing may effect the permanency of repair. The routing operation consists of cutting a groove at the surface that is sufficiently large to receive the sealant, using a concrete saw or hand tools. A minimum surface width of routing of 6 mm is desirable, as repairing the narrower grooves is difficult. The surfaces of the routed joints should be cleaned with an air jet and allowed to dry before placing the sealant.

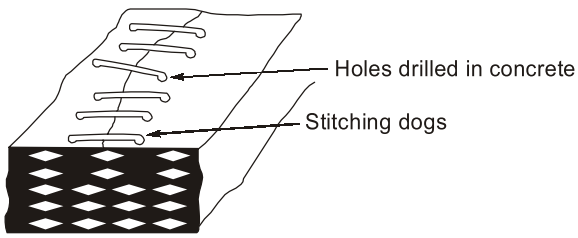



Crack repair by routing and sealing

   The function of the sealant is to prevent water from reaching the reinforcement, hydrostatic pressure from developing within the joint, staining the concrete surface, or causing moisture problems on the far side of the member.

   The epoxy compounds are often used as sealant material. Hot-poured joint sealants are used when through watertightness of joints is not required and the appearance is not important. Urethanes, which remain flexible through large temperature variations, have been used successfully in sealing the cracks up to 20 mm in width and of considerable depth.

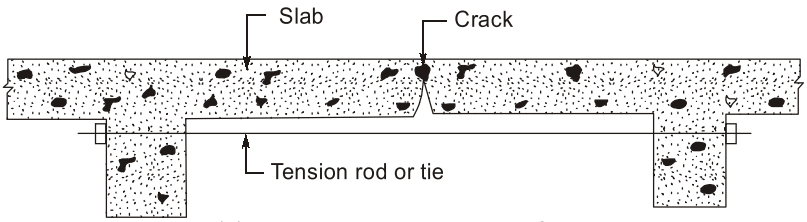
2. **Stitching of Cracks** : The stitching procedure consists of drilling holes on both sides of the crack, cleaning the holes, and anchoring the legs of the stitching dogs (U-shaped metal units with short legs are shown in figure), that span the crack, with either a non-shrink grout or an epoxy resin-based bonding system. The stitching dogs should be variable in length and orientation or both, and should be so located that the tension transmitted across the crack is not applied to a single plane within the section but spread over an area. The spacing of stitching dogs should be reduced at the ends of cracks.



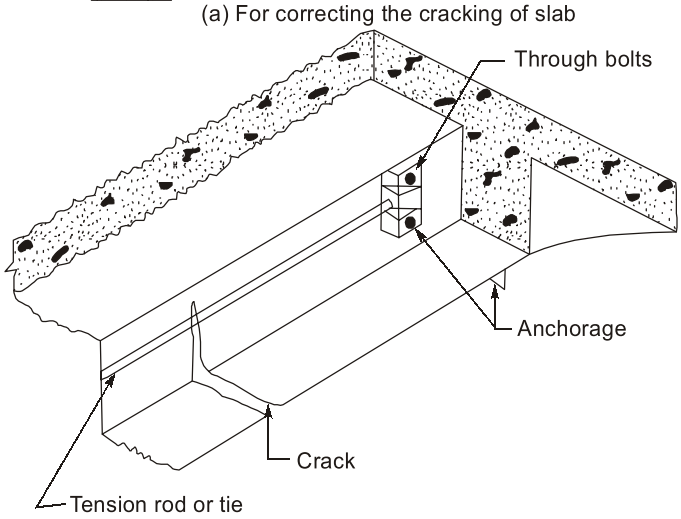

Repair by stitching the cracks

Stitching may be used when tensile strength of the member is to be re-established across major cracks. Stitching does not close a crack but can prevent it from propagating further. Stitching tends to stiffen the structure which may accentuate the overall structural restraint, causing the concrete to crack elsewhere. It may, therefore, be necessary to strengthen the adjacent sections using external reinforcement embedded in a suitable overlay.

In the case of bending members, the stitching is done on the tension face where the movement is occurring. If the member is in a state of axial tension, the dogs must be placed symmetrically even if excavation or demolition is required to gain access to opposite sides of the section. The dogs are relatively thin and long and cannot take much compressive force. Accordingly, if there is a tendency for the cracks to close as well as to open, the dogs must be strengthened by encasement in an overlay. In water-retaining structures, the crack must be first made watertight before the stitching begins. The remedial measures for repairing the structural cracking of a slab, and a beam are shown in figure (a) and (b), respectively.




(a) For correcting the cracking of slab




(b) For correcting the cracking of beam

**Repair of flexural cracks in slab and beam**

3. **Grouting** : The wide and deep cracks may be repaired by filling them with Portland cement grout. The grout mixtures may contain cement and water or cement, sand and water, depending upon the width of the crack. However, the water-cement ratio should be kept as low as practicable to maximize strength and minimize shrinkage. Water-reducing admixtures may also be used to improve the properties of the grout. The procedure consists of cleaning the concrete along the crack; providing built-up grout ports (nipples or seats) at intervals, sealing the crack between the ports with a cement paint or sealant, etc., testing the seal and then grouting the whole area. After the crack is filled, pressure should be maintained for several minutes to ensure good penetration. The method is particularly useful for repairing wide cracks in gravity dams, concrete walls, etc.

For narrow cracks in concrete, chemical grouts consisting of solutions of two or more chemicals that combine to form gel, a solid precipitate, can be advantageously used. The chemical grouts are also applicable in moist environment and provide wide limits of control of gel time.

**3.18 (i) What are the arrangements needed at a typical concrete plant? List the typical activities in such plants.**

**(ii) What are the various ways by which concrete can be transferred from the central batch and mixing plant to work site?**

**[IFS (Mains) 2022 : 8 + 7 Marks]**

**Solution:**

**(i)**

Following arrangements are needed at a typical concrete plant:

1. Information regarding materials.
2. Storage arrangement for sand, aggregates and cement.
3. Weight arrangements for aggregates, sand and cement.
4. Types of mixer

   Example :

   1. Non-tilting reversible drum concrete mixer.
   2. Double conical tilting mixer.
5. Controls through individual levers or push buttons for opening of gates for batching plants.
6. Ready mixed concrete plants shall be equipped with computer, monitor and printer.
7. Additional facilities: 4.1 (9) page 2 IS 4928 : 2004

**Typical activities in such plants are**

1. Powder feeding : It involves pouring of cement into the mixer.
2. Aggregate feeding : It involves feeding of coarse and fine aggregates.
3. Water : It is added to have hydration of cement.
4. Addition of admixtures, transportation and storage.

**(ii)**

Following are the various ways by which concrete can be transferred from the central batch or mixing plant to work site:

1. If the concrete is to be placed at or below the mixer level, steel wheel borrows can be employed. (if distance is relatively larger then power borrow can be used).
2. When concrete is required below ground level, a wooden or steel chute may be used.
3. Transportation of dry mixes can be done by dumpers or ordinary open-steel body tipping lorries upto hauls of less than 5 km.
4. Steel buckets transported by rail or road may be used to transport the concrete for long distances in case of dams, bridges.
5. Truck mixers and agitator lorries are be used transport ready-mixed concrete.
6. Conveyor belts are employed for conveying fairly stiff concretes.
7. Hoists can be used in case lifting of concrete is required to greater heights.
8. Pumping of concrete through steel pipelines can be used in construction of multi-storey buildings, tunnels bridges.

**3.19 What is curing of concrete? Explain in brief various methods that are being adopted at the site for curing of concrete.**

**[10 marks : 2021]**

**Solution:**

Curing is the process of keeping concrete damp (sufficient water should be made available to concrete) to achieve full strength by making up the water lost due to evaporation thereby making available the water required for hydration of cement in concrete.

- **Water Curing** is done by covering the concrete surface with gunny bags and then sprinkling water over them regularly or with water proof paper.
- **Steam Curing:** Curing can be also accomplished by artificial heat while the concrete is maintained in moist condition.
- **Curing by Infra Red Radiation**:A much more rapid gain of strength can be obtained with the help of infra red radiation than even with steam curing. The rapid initial rise of temperature does not affect the ultimate strength.
- **Electrical Curing** : Concrete products can be cured by passing alternating current of low voltage and high amperage through electrodes in the form of plates covering the entire area of two opposite faces of concrete.
- **Chemical Curing** : Chemical membranes can be sprayed on to cure concrete. Liquid membrane forming curing compounds such as sodium silicate (water glass) solution retard or prevent evaporation of moisture from concrete.

**3.20 What are the different types of deterioration of concrete ? How can it be prevented?**

**[IFS (Mains) 2022 : 8 Marks]**

**Solution:**

**Following are the different types of deterioration of concrete:**

(i) Abrasion, erosion and cavitation.

Prevention : These can be prevented by application of surface - hardening solutions.

Ex : Sodium silicate

(ii) Crystallization of salts in pores

Prevention: Desalination, use of surfactants etc.

(iii) Frost action:

Prevention: Air entrainment reduces risk of damage to concrete by frost action.

(iv) Deterioration due to reaction between aggressive fluid and components of hardened cement parts.

Prevention : Adjust $p^H$ of the aggressive fluid.

(v) Deterioration due to reaction involving hydrolysis and leaching of the components of hardened cement parts.

Prevention : Use hard water.

(vi) Deterioration due to sulphate attack.

Prevention : A low permeable concrete is the best protection against sulphate attack.

**Some other measures for the prevention of deterioration or concrete are as follows:**

1. The cement content should be such that it ensures sufficient alkalinity to prevent corrosion of reinforcement.
2. The water-cement ratio and the cement content must provide enough paste to overfill the voids in compacted concrete.

3. Use of Portland slag cement or Portland pozzolana cement is advantageous for concreting in seawater.
4. Use of Portland cement having $C_3A$ content of less than 5% is suitable for concreting under a sulphate environment.
5. The super-sulphated cement provides acceptable durability against an acidic environment.
6. Addition of hydraulic additives is also helpful in preventing the deterioration of concrete.
7. It is possible to attain a marked improvement in the quality of concrete by encouraging natural or artificial carbonation of the surface layer.
9. The durability of concrete can also be increased by impregnating the pores with a suitable polymer.

## 4. Stones, Bricks and Bricks Masonry

**4.1 (i) Compare brick masonry with stone masonry.**
**(ii) State general principles which shall be observed in brick masonry works.**

**[5 × 2 = 10 marks : 2005]**

Solution:

(i)

| Description | Stone Masonary | Brick Masonary |
|---|---|---|
| 1. Uses | Construction of piers, dams, docks, marine structures, residential and monumental buildings | Residential buildings |
| 2. Strength | High crushing strength | Much less |
| 3. Durability | Excellent | Excellent |
| 4. Danger from dampness | No such danger | Causes disintegration |
| 5. Cost | High Cost. It's restricted to areas where stone is plenty | Much less cost, easily available |
| 6. Bond | It requires a great deal of time and extra labour in maintaining proper bond | Regular shape and size result in quick construction bond |
| 7. Source | Natural | Artificial |
| 8. Construction | Requires high skill | Ordinary skill required |
| 9. Moulding into desired shape | Not convenient | Convenient |
| 10. Handling | Requires lifting device | Easy to handle |

(ii) General principles in brick masonry:

1. The bricks should be hard, well burnt and tough with uniform colour, shape and size.
2. The bricks should be laid on their beds with frogs pointing upwards.
3. The courses should be truly horizontal and should have truly vertical joints.
4. Use of brick bats should be avoided to the maximum possible extent.
5. Generally, the height of brick masonry construction in a day is limited to 1.5 m.
6. In order to ensure continuous bond, the walls should be stopped with the toothed end at the end of each stage of construction.
7. Finished brickwork should be cured for atleast 2-3 weeks where lime mortar is used and for 1-2 weeks where cement mortar is used.

**4.2 Explain merits and demerits of brick and stone masonry.**

**[10 marks : 2009]**

Solution:

Brick masonry have several advantages over stone masonry.

- Since the shape and size of bricks are uniform, it does not need highly skilled labour in construction.

- As bricks are light, they can be handled easily.
- Thinner walls can be constructed with bricks.
- In brick masonry, it is easy to form openings for doors and windows.
- Dead load of masonry is less.
- Brick masonry has good fire and weather resistance.
- It is possible to use all types of mortar in brick masonry.
- Bricks are easily available around cities and their transportation cost is less. The transportation cost of stones is higher as they are heavy and have to brought from quarries, which are located far away from cities.

There are also some disadvantages with brick masonry:

- The strength of brick masonry is lower than that of stone masonry.
- Brick masonry is less durable.
- Brick masonry needs plastering and plastered surface needs colour washing/painting. Hence, maintenance cost of brick masonry is high.
- Stone masonry gives massive appearance and hence monumental buildings are built with stone masonry.

**4.3 (i) What are harmful substances in brick earth?**
**(ii) What is efflorescence in bricks? What are its causes and remedies?**

**[5 + 5 = 10 marks : 2010]**

Solution:

(i) **Harmful substances in brick earth.**

(a) **Excess lime:** When a desirable amount of lime is present in the clay, it results in good bricks, but if in excess, it changes the colour of the brick from red to yellow.

(b) **Pebbles, gravels, grits :** do not allow the clay to be mixed thoroughly and spoil the appearance of the brick. Bricks with pebbles and gravels may crack while working.

(c) **Iron pyrites :** They tend to oxidise and decompose the brick during burning. The brick may split into pieces. Pyrites discolourise the bricks.

(d) **Alkalis :** Alkalis forming less than 10% of the raw clay, are of great value as fluxes especially when combined with silicates of alumina. It is the form of soda or potash.

(e) **Organic matter :** On burning green bricks, the organic matter get charred and leave pores making the bricks porous, the water absorption is increased and strength is reduced.

(f) **Carbonaceous Materials :** It is the form of bituminous matter or carbon greatly affect the colour of raw clay.

(g) **Sulphur :** It will cause formation of spongy, swollen structure in the brick and the brick will be decoloured by white botches.

(h) **Water :** A large proportion of free water generally causes clay to shrink considerably during drying whereas combined water causes shrinkage during burning.

(ii) **Efflorescence in bricks :** This defect is caused because of alkalies present in the bricks. When bricks come in contact with moisture, water is absorbed and the alkalis crystallise. On drying grey or white powder patches appear on the brick surface. This can be minimised by selecting proper clay materials for brick manufacturing, preventing moisture to come in contact with the masonry, by providing waterproof coping and by using water repellentmaterials in mortar and by providing damp proof course.

**Remedy :** The only satisfactory treatment may be to render the wall after removing all loose material and raking out the mortar which may itself be impregnated.

**4.4** Write about requirements, purpose of constructing cavity walls. Give the general specifications of constructing these walls.

[10 marks : 2011]

Solution:

**Requirement and purpose of constructing cavity walls :** A cavity wall or hollow wall is the one which consists of separate walls called leaves or skins, with a cavity or gap in-between. The two leaves of a cavity wall may be of equal thickness if it is non-load bearing or internal leaf may be thicker than the external leaf to meet the structural requirements. Cavity walls are constructed for

- Giving better thermal insulation to building (25% greater than solid walls)
- It also prevents the dampness to enter and act as sound insulation. Hence, they are normally the outer walls of the building.
- The nuisance of efflorescence is also very much reduced.
- They are cheaper and economical.
- Loads on foundations are reduced because of lesser solid thickness.
- It also acts as sound insulation.

**General specification of constructing cavity walls:**

- The size of cavity varies from 4 to 10 cm.
- The inner and outer skins should not be less than 10 cm each (half brick)
- The width of the cavity is other key part of the specification of this form of wall. The cavity only works if the width of the cavity at all points can be kept under tolerances and clean.
- The cavity should be atleast 25 mm if it is to achieve the thermal insulation potential of the still air providing good surface resistance on both sides of cavity so the 50 mm is satisfactory for thermal function.

**4.5** State the importance of bonding in brick work. Point out the difference in English bond, Single flemish bond and Double flemish bond. Illustrate your answer with suitable sketches.

[8 marks : 2013]

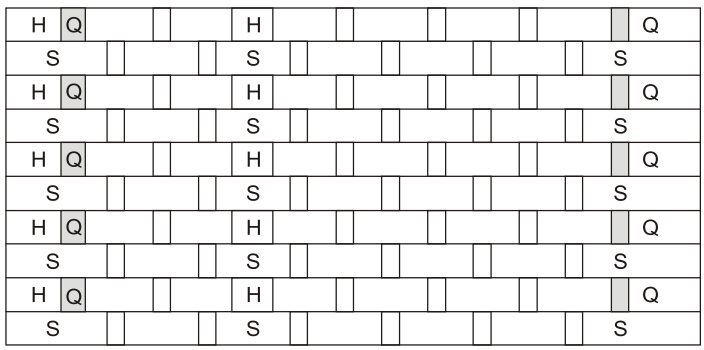
Solution:

**Importance of bonding in brickwork:** The bond is the interlacement of bricks formed when they lay (or project beyond) those immediately below or above them.

The art of bonding brickwork consists of the orderly arrangement of the bricks in such a way that continuous or through joints at right angles to the face of the wall are eliminated and longitudinal through joints along the wall are also reduced to a minimum. Bonding helps in distribution of loads. Bonding is carried by use of closures (in the header course) or three quarters in the stretcher courses.

**Single flemish bond :** Single flemish bond is comprised of double flemish bond facing and English bond backing and hearting in each course. The bond thus uses the strength of the English bond and appearance of flemish bond.

However the bond can be used for those walls having thickness at least equal to $1\frac{1}{2}$ brick. Double flemish bond facing is done with good quality expensive bricks.



Flemish bond

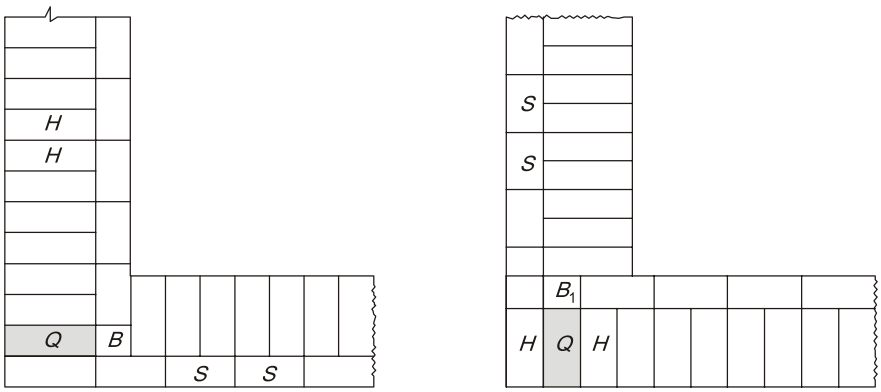
**Double flemish bond :** In double flemish bond, each course presents the same appearance both in front face as well as in the back face. Alternate headers and stretchers are laid in each course. Because of this, double flemish bond presents better appearance than English bond.

Comparison of English bond and Flemish bond:

1. English bond in stronger than flemish bond for walls thicker than $1\frac{1}{2}$ brick.
2. Flemish bond give more pleasing appearance than the English bond.
3. Broken bricks can be used in the form of bats in Flemish bond. However, more mortar is required.

**English bond :** This bond consists of alternate courses of header and stretches. In this arrangement, vertical joints in the header courses came over each other and the vertical joints the stretcher course are also in the same line. For breaking of vertical joints in the stretcher course are in the same line. For breaking of vertical joints in the successive course it is essential to place queen closer after the first header in each heading course. The following additional points should be noted:

1. A heading course should never start with queen closer as it is liable to get displaced in this position.
2. In the stretcher course, the stretcher should have a minimum lap of 1/4th their length over the headers.
3. In walls having their thickness equal to odd number of half brick, i.e., $1\frac{1}{2}$ brick thick wall or $2\frac{1}{2}$ brick thick wall and so on the same course will show stretches on one face and headers on the other.




1, 3, 5 ..... courses

2, 4, 6 courses

Plane for 1½ brick thick wall

## 4.6 What are objects of providing plastering and pointing to the exposed surface? With neat sketches describe various type of pointing.

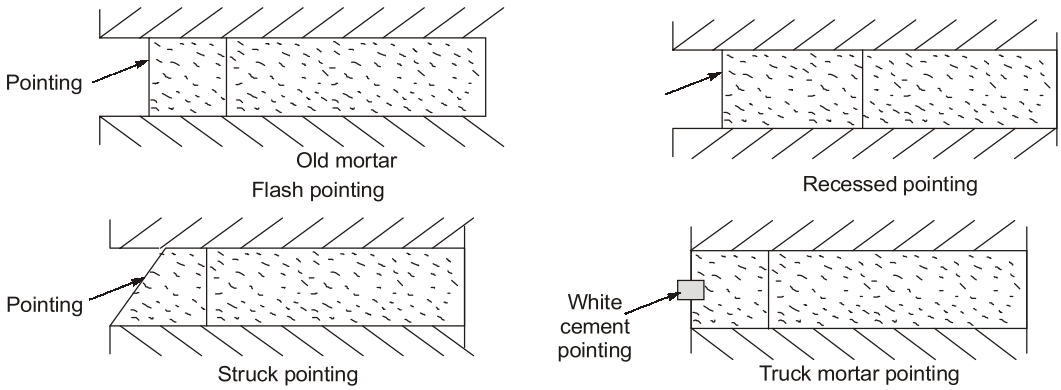
[5 marks : 2013]

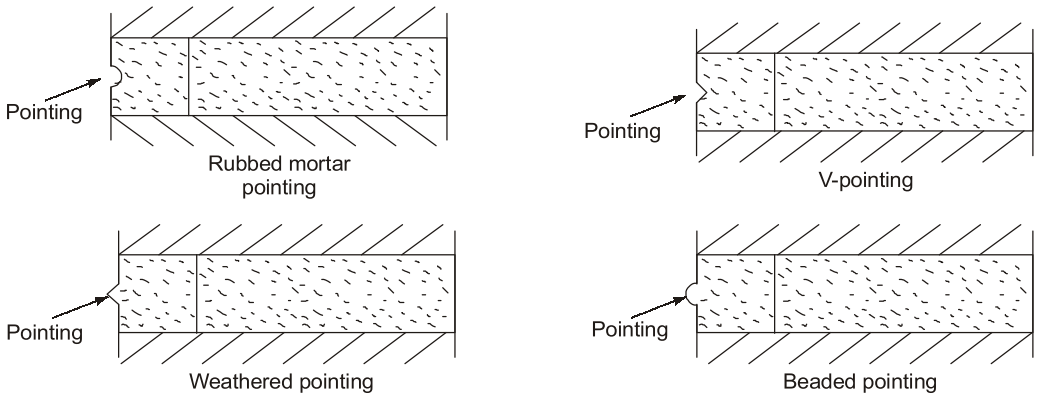
Solution:

**Objects of providing plastering and pointing :** The objects are as follows:

- To improve the appearance of the structure as a whole and to give smooth surface.
- To protect the exposed surface from the effects of atmosphere action.
- To rectify the defective workmanship or to conceal inferior materials.

**Types of pointing with sketches :** The different types of pointing along with sketches are shown below:






**4.7 List out different methods of damp prevention in building.**

[3 marks : 2015]

Solution:

1. Brick bat lime soba treatment
2. Mud phuska treatment
3. Bitumen coating with sand sprinkling
4. Bitumen felt treatment and glass fibre felt treatment
5. China mosaic treatment
6. Indian waterproofing method
7. Epoxy painting or grouting
8. Mastic asphalt
9. Water proofing by crystallization
10. Polyurethane liquid membranes water proofing.
11. Silicon based water repellent.

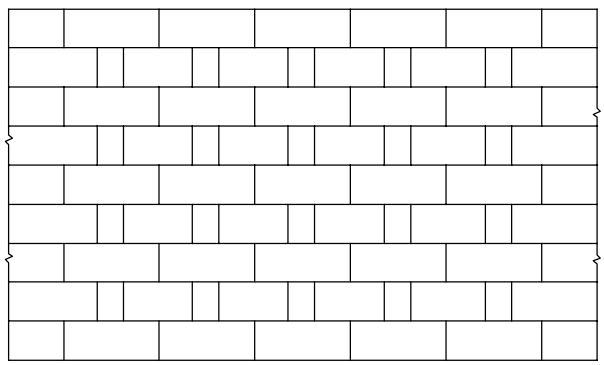
**4.8 Differentiate Rubble and Ashlar masonry. Mention further classification of Rubble masonry.**

[5 marks : 2015]

Solution:

**Ashlar Masonry :** Ashlar masonry consists of blocks of accurately dressed stone with extremely find bed and end joints. The blocks may be either square and rectangular shape. Various types are as:

1. **Ashlar fine tooled :** It is finest type of stone masonry.



Fine tooled Ashlar masonary

2. **Ashlar Chamfered :** This is a special form of rock-faced ashlar masonry in which the strip provided around the perimeter of the exposed face is chamfered or bevelled.