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Detailed Solutions

ESE-2025 Mains Test Series

Civil Engineering Test No : 5

Section A : Building Material + Construction Practice

Q.1 (a) Solution:

The dry process is one of the two principal methods used for manufacturing portland cement. It is adopted when the raw materials (limestone and clay) are hard and moisture content is low. This process is more energy-efficient and modern compared to the wet process.

(i) Raw materials are crushed separately using crushers and ball mills to form fine powdered particles.

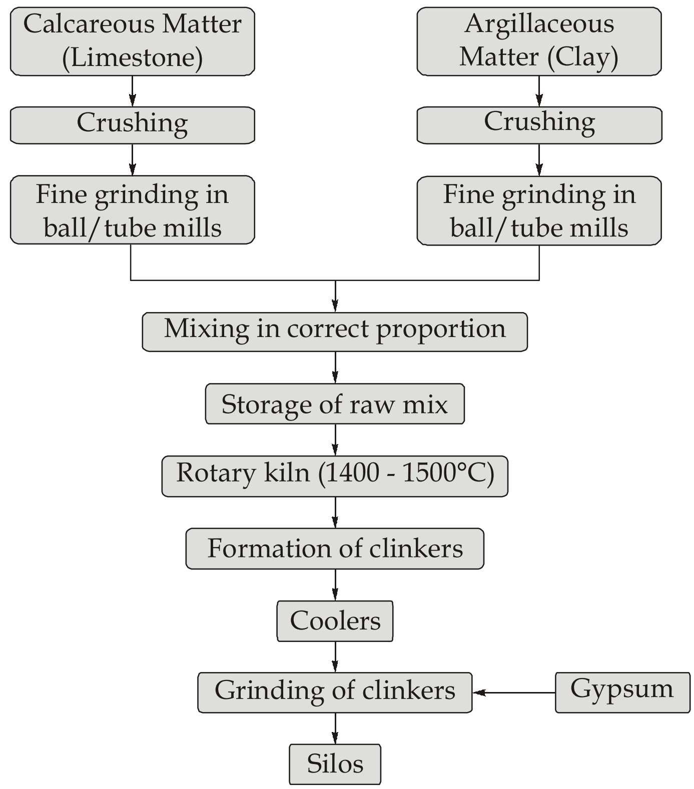
(ii) The powdered materials are mixed thoroughly to form a uniform raw mix.

(iii) The dry mix is fed into a rotary kiln. Calcination occurs and clinkers are obtained as a result of incipient fusion and sintering at a temperature of about 1400ºC - 1500°C.

(iv) Ferric oxide acts as a flux due to its lower melting point and promotes fusion of other oxides during clinkering.

(v) Rapid cooling of clinkers is done to preserve metastable compounds.

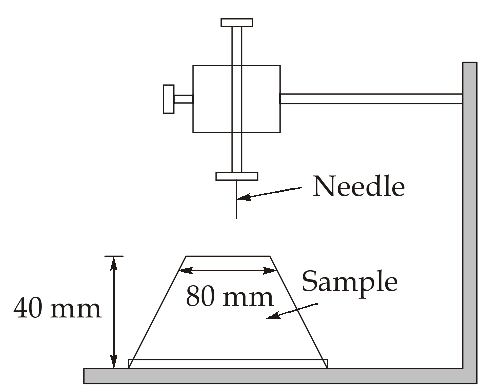
(vi) About 3-5% gypsum is added to control setting time while the mixture is ground to a fine powder and is then stored in silos.



Flow diagram for dry process of manufactures of cement.

Q.1 (b) Solution:

When water is added to cement, the resulting paste starts to stiffen and gain strength and lose the consistency simultaneously. The term setting implies solidification of the plastic cement paste. Initial and final setting times may be regarded as the two stiffening states of the cement. The beginning of solidification, called the initial set, marks the point in time when the paste has become unworkable. The time taken to solidify completely marks the final set, which should not be too long in order to resume construction activity within a reasonable time after the placement of concrete. Vicat's apparatus is used for testing both initial and final setting times.



Vicat's apparatus

Test Procedure:

(i) A neat cement paste is prepared by gauging cement with 0.85 times the water required to give a cement paste of standard consistency.

(ii) Stopwatch is started at the instant water is added to the cement.

(iii) Initial setting time is referred to as the time after which a square needle of size '1 mm' fails to pierce the block by about 5 mm measured from the bottom.

(iv) Final setting time is referred as the time after which needle at the center of an annular collar marks an impression over the block but the collar fails to do so.

As per IS code:

Initial setting time ≥ 30 minutes

Final setting time ≤ 600 minutes (10 hours)

Q.1 (c) Solution:

Seasoning is the process of removing moisture from freshly felled timber to make it suitable for use in construction or manufacturing. The goal is to bring the moisture content close to the average humidity of the area where it will be used.

Objectives of seasoning:

1. Reduce shrinkage and warping after placement in structure.
2. Increase strength, durability and workability.
3. Reduce weight for easier handling.

Preservation is the process of physical or chemical treatment of timber in order to protect it from fungi, insects, moisture, decay etc.

Difference between seasoning and preservation:

Aspect	Seasoning	Preservation
Purpose	To reduce the moisture content in timber	To protect timber from decay, fungi and other harmful factors.
Main benefit	Improves strength, durability, and workability.	Increases service life by resisting biological attack and moisture degradation.
When applied	Immediately after felling	Usually after seasoning or before exposure

Methods of seasoning:

(i) Natural or Air Seasoning: The log of wood is sawn into planks of convenient sizes and stacked under a covered shed in crosswise direction in alternate layers so as to permit free circulation of air. The duration for drying depends upon the type of wood and the size of planks. The rate of drying is however very slow. Air seasoning reduces the moisture content of the wood to 12-15 percent. It is used very extensively in drying ties and the large size structural timbers.

(ii) Water Seasoning: The logs of wood are kept completely immersed in running stream of water, with their larger ends pointing upstream. Consequently, the sap, sugar, and gum are leached out and are replaced by water. The logs are then kept out in air to dry. It is a quick process but the elastic properties and strength of the wood get reduced.

Methods of preservation:

(i) Chemical treatment: Preservatives like creosote, copper based salts are forced into the timber under pressure. It offers deep and lasting protection against rots and insects.

(ii) Hot and Cold Process ensures sterilisation against fungi and insects. The timber is submerged in the preservative solution, which is then heated to about 90° to 95°C and maintained at this temperature for a suitable period depending on the charge. It is then allowed to cool until the required absorption is obtained. During the heating period, the air in the timber expands and is partially expelled. While cooling, the residual air in the timber contracts and creates a partial vacuum which causes the preservative to be sucked into the timber.

Q.1 (d) Solution:

(i)

Some common impurities found in lime are:

Magnesium Carbonate:

Presence of this constituent allows the lime to slake and set slowly, but imparts high strength. Further, the production of heat and expansion are low. The magnesium limestones are hard, heavy and compact in texture.

Magnesium limestones display irregular properties of calcination, slaking and hardening. Up to 5 percent of magnesium oxide imparts excellent hydraulic properties to the lime.

Clay: It is mainly responsible for the hydraulic properties of lime. It also makes lime insoluble in water. The percentage of clay to produce hydraulicity in lime stones usually varies from 10 to 30. If, it is in excess, it arrests slaking whereas, if in small quantities the slaking is retarted. Thus, limes containing 3-5 per cent of clay do not display any hydraulic property and do not set and harden under water. Whereas, when clay is present as 20-30 per cent of lime, the latter exhibits excellent hydraulic properties and is most suitable for aqueous foundations.

Silica: In its free form (sand) has a detrimental effect on the properties of lime. Limes containing high percentage of free silica exhibit poor cementing and hydraulic properties. Limes containing 15-20 per cent of free silica are known as poor limes.

Iron Compounds: Iron occurs in small proportions as oxides, carbonates and sulphides. They are converted into Fe_2O_3 at lower temperatures of calcination. At higher temperatures iron combines with lime and silicates and forms complex silicate compounds. Pyrite or iron sulphide is regarded to be highly undesirable. For hydraulic limes 2-5 per cent of iron oxide is necessary.

Carbonaceous Matters: Carbonaceous matters in lime are seldom present. Its presence is an indication of the poor quality of lime.

Sulphates: Sulphates, if present, slow down the slaking action and increase the setting rate of limes.

Alkalis: When pure lime is required the alkalis are undesirable. However, up to 5 per cent of alkalis in hydraulic limes do not have any ill effect but improve hydraulicity.

(ii)

Bureau of Indian Standards has classified lime into class *A*, *B*, *C*, *D*, *E* and *F* based on the purpose of its use in construction.

Class *A* - Eminently Hydraulic Lime is used for making mortar and concrete for construction and foundation works, i.e. for structural purposes.

Characteristics

(i) Its colour is grey.
(ii) Calcium oxide and clay are 60-70 and 25 per cent respectively,
(iii) Slakes with difficulty.
(iv) Sets and hardens readily under water with initial setting time of 2 hours and final setting time of 48 hours.

Class *B* - Semi Hydraulic Lime is used for masonry mortars, flooring and for concrete in ordinary constructions and plaster undercoat.

Characteristics

(i) Its colour is grey.
(ii) Contains 70 per cent calcium oxide and 15 per cent clay.
(iii) Slakes and sets at slow rate taking about a week to set under water.

Class C - Fat Lime is used for finishing coat in plastering, white washing and with pozzolana in mortars.

Characteristics

(i) Its colour is white.
(ii) Slakes vigorously and increases by two to three times of its original volume.
(iii) Contains about 93 percent calcium oxide and about 5-7 per cent clay.

Class D - Magnesium/Dolomitic Lime is used for finishing coat in plastering and white washing

Characteristics

(i) Its colour is white.

(ii) Contains about 85 per cent calcium and magnesium oxides.

(iii) Slakes promptly.

(iv) Sets slowly

Class E - Kankar Lime is used for making masonry mortars, plastering and white washing.

Characteristics

(i) Its colour is grey

(ii) Contains 20 per cent calcium oxide, 5 per cent magnesium oxide and remaining impurities.

(iii) Slakes and sets slowly.

Class F - Siliceous Dolomitic Lime is used for undercoat and finishing coat of plaster

Q.1 (e) Solution:

(i)

Precautions for Application of Cement Paint:

1. The cement paint should not be applied on surfaces which are already treated with whitewash, colour wash and dry distemper unless the surface is thoroughly scraped and cleaned properly.
2. Care must be taken to ensure a continuous application of cement paint because it hardens fast. Brushes used should be wetted as often as possible to prevent hardening.
3. As cement paint sets hard, all splashes must be immediately removed with water.
4. Scaffolding must be independently tied to allow uninterrupted application. Any faults/cracks in the structure, particularly those which may lead to moisture penetration must be rectified.
5. The cement paint should not be applied in direct sunlight.
6. A minimum wait period of 24 hours should be allowed for the first coat to harden before applying the second coat.
7. The cement paint should not be applied in rain or when temperature is below 5°C or if exposure to these conditions is likely during setting and curing.

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(ii)

Advantages of cement paints are:

1. Being cement based, cement paints are compatible with cement rendered surfaces.
2. They can be applied on damp surfaces as water retained on the surface helps in the curing process; whereas oil paints or OBD cannot be used on damp surfaces.
3. Cement paints have water repellent properties to shed off water and dampness.
4. Other paints can subsequently be painted on a surface painted with cement paint. Hence, in many cases, cement paint is used as the first paint for a new house and one or two year after the walls have dried, other decorative paint can be used for better appearance.
5. Painting with cement paint requires lesser skill
6. Alkalinity of walls due to use of lime, does not affect the cement paint. Walls once whitewashed with lime can be painted with cement paint after a delay of a few months, after the effect of lime has vanished
7. It is possible to apply a fungicidal wash on walls before the cement paints are coated.
8. Cement paints have good fire resistance. They have no toxic of fire hazard and some of them may meet class zero fire rating when applied to noncombustible substrates.
9. Cement paints have good weather resistance and durability. They will resist the penetration of external water whilst allowing the structure to breathe.
10. These paints may be applied by paint brush or paint roller or spray gun.

Disadvantages of cement paints are:

1. The walls has to be wetted before the cement paint is applied to give the paint a good bond.
2. Similarly, the walls should not be too smooth as otherwise the cement paint may not adhere to the surface.
3. Most of cement paints require water curing except the recently developed varieties. Water curing inside the rooms already occupied is difficult during repainting.
4. Cement paint should not be applied on surfaces which are painted by oil paints or have gypsum plaster without removing these coats.

Q.2 (a) Solution:

(i)

Ferrocement: Ferrocement is a type of thin-wall reinforced concrete construction where small-diameter wire meshes are used as reinforcement and are impregnated with a rich cement mortar mix. It does not include coarse aggregates. The reinforcement consists of layers of mesh (such as chicken mesh or woven wire mesh), sometimes supported with small-diameter steel rods (skeletal reinforcement).

Advantages of Ferrocement:

1. High tensile strength due to closely spaced wire meshes.
2. Better crack control and durability.
3. Can be moulded into thin, curved sections.
4. Economical for small-scale applications.
5. Requires less skilled labour compared to *RCC*.

Applications of Ferrocement:

1. Water tanks, boats, silos, and biogas tanks.
2. Precast roofing channels and ferrocement shells.
3. Rural sanitation units and affordable housing.
4. Manhole covers, pipes, and cover slabs.

Fibre reinforced concrete:

Fibre Reinforced Concrete (FRC) is concrete containing fibrous materials uniformly distributed and randomly oriented. These fibres act as crack arrestors and improve the tensile strength, toughness, and ductility of concrete. Common types of fibres include steel, glass, synthetic fibres (like polypropylene), and natural fibres. FRC improves the behavior of concrete under load and especially enhances post-cracking performance. It is used where control of plastic shrinkage cracks and improved impact resistance are important.

Advantages of Fibre Reinforced Concrete:

1. Reduces microcracks and plastic shrinkage.
2. Enhances tensile and flexural strength.
3. Improves resistance to impact and fatigue.
4. Increases ductility and post-cracking toughness.
5. Enhances abrasion and freeze-thaw resistance.

Applications of Fibre Reinforced Concrete:

1. Industrial floors, pavements, and precast segments.
2. Tunnel linings and slope stabilisation (shotcrete).
3. Airport runways and bridge decks.
4. Earthquake-resistant and blast-resistant structures.

(ii)

Bacterial Concrete (also known as self-healing concrete or bio-concrete) is a type of concrete in which specific type of bacteria are added to the mix to improve its durability and help it repair minor cracks automatically.

The principle behind bacterial concrete is the use of bacteria such as Bacillus Pasteurii or Bacillus Sphaericus, which can survive in the alkaline environment of concrete. These bacteria are mixed with nutrients like calcium lactate. When cracks form and water seeps in, the dormant bacterial spores become active and start consuming the nutrients. As a result, they produce calcium carbonate ($CaCO_3$) as a metabolic by-product, which fills up the cracks and seals them. This process is called microbial induced calcite precipitation (MICP).

Advantages:

- Automatically seals microcracks thereby increasing durability.
- Reduces water permeability.
- Improves resistance to corrosion, especially in reinforced concrete.
- Reduces maintenance cost of the structure.

Limitations:

- High initial cost due to bacterial culture and nutrients.
- Not effective for wide cracks or structural failures.
- Long-term performance under field conditions is still under research.

Q.2 (b) Solution:

(i)

Given,

$$w_c = 165 \text{ kg/m}^3$$

From durability point of view,

$$\text{Maximum w/c ratio} = 0.45$$

$$\text{In 1 m}^3 \text{ of concrete, water} = 165 \text{ kg} \qquad \text{...(Given)}$$

$$\therefore \quad \text{In 1 m}^3 \text{ of concrete, cement} = \frac{165}{0.45} = 366.67 \text{ kg}$$

$$\text{Volume of water in the mix, } V_W = \frac{165 \text{ kg}}{1000 \text{ kg/m}^3} = 0.165 \text{ m}^3$$

$$\text{Volume of cement in the mix, } V_C = \frac{366.67}{3.10 \times 1000} = 0.1183 \text{ m}^3$$

$\therefore$ Volume of coarse aggregate + Volume of fine aggregate = 1 – 0.165 – 0.1183

$$\Rightarrow \quad V_{CA} + V_{PA} = 0.7167 \text{ m}^3 \qquad \text{...(i)}$$

Since, it is given that mortar content is 58% by volume,

$$\therefore \quad V_W + V_C + V_{FA} = 0.58$$

$$\Rightarrow \quad 0.165 + 0.1183 + V_{FA} = 0.58$$

$$\Rightarrow \quad V_{FA} = 0.2967 \text{ m}^3$$

Now, from equation (i),

$$V_{CA} + V_{FA} = 0.7167$$

$$\Rightarrow \quad V_{CA} = 0.7167 - 0.2967$$

$$\Rightarrow \quad V_{CA} = 0.42 \text{ m}^3$$

$$\text{Weight of sand} = 0.2967 \times 2.68 \times 1000$$

$$= 795.156 \text{ kg}$$

$$\text{Weight of coarse aggregates} = 0.42 \times 2.74 \times 1000$$

$$= 1150.8 \text{ kg}$$

$$\therefore \quad \text{Cement content} = 366.67 \text{ kg/m}^3$$

$$\text{Sand content} = 795.156 \text{ kg/m}^3$$

$$\text{Coarse aggregate content} = 1150.8 \text{ kg/m}^3$$

(ii)

1. **Size of Aggregate:**

   The size of aggregate directly affects the surface area to be wetted by the cement paste. Large aggregates reduce the total surface area, thereby requiring less paste and improving workability. Conversely, small aggregates increase surface area and reduce workability unless compensated by more water or paste. However, too large an aggregate may cause segregation and hinder smooth placement.

2. **Cement Content:**

   An increase in cement content generally enhances workability due to the greater availability of paste for lubrication between particles. This facilitates easier mixing, placing, and compaction. However, excessive cement may lead to increased shrinkage and cost, and therefore must be optimized.

3. **Water-Cement Ratio:**

   Water-cement ratio is one of the most influential parameters in determining workability. A higher water-cement ratio increases fluidity and ease of handling, but beyond a point, it weakens the concrete and may lead to segregation. A lower water-cement ratio improves strength but reduces workability, necessitating the use of admixtures or improved compaction techniques.

4. **Entrained Air:**

Air-entraining agents introduce tiny, uniformly distributed air bubbles in the concrete. These bubbles act as internal lubricants, improving workability without the need for additional water. They also improve cohesion, reduce bleeding, and are particularly beneficial in harsh mixes or in freezing environments.

Q.2 (c) Solution:

(i)

The chemical reaction between cement and water is known as hydration of cement. The reaction takes place between the active components of cement (C_4AF, C_3A, C_3S and C_2S) and water. The factors responsible for the physical properties of concrete are the extent of hydration of cement and the resultant microstructure of the hydrated cement.

When the cement comes in contact with water, the hydration products start depositing on the outer periphery of the nucleus of hydrated cement. This reaction proceeds slowly for 2-5 hours and is called induction or dormant period. As the hydration proceeds, the deposit of hydration products on the original cement grain makes the diffusion of water to unhydrated nucleus more and more difficult, consequently reducing the rate of hydration with time. At any stage of hydration, the cement paste consists of gel (a fine-grained product of hydration having large surface area collectively), the unreacted cement, calcium hydroxide, water and some minor compounds.

The crystals of the various resulting compounds gradually fill the space originally occupied by water, resulting in the stiffening of the mass and subsequent development of the strength.

The primary products of hydration are:

- Calcium Silicate Hydrate (C—S—H): An amorphous gel, largely responsible for strength (resembles the mineral tobermorite)
- Calcium Hydroxide ($Ca(OH)_2$): Also known as portlandite, contributes little to strength and is more vulnerable to chemical attack

Hydration reactions of major compounds:

1. Tricalcium Silicate (CS):

$$2\,C_3S + 6H_2O \rightarrow C-S-H + \underset{\text{(Portlandite)}}{3Ca(OH)_2}$$

   - High early strength
   - High heat evolution
   - Main contributor of strength up to 7 days

2. Dicalcium Silicate (C_2S):

   $2C_2S + 4H_2O \rightarrow C-S-H + Ca(OH)_2$

   - Low early strength, but gains strength over time
   - Low heat of hydration
   - Dominant beyond 28 days

3. Tricalcium Aluminate (C_3A):

   $C_3A + H_2O \rightarrow C_3AH_6$ (Ettringite)

   $C_3A + H_2O + Ca\,SO_4 \rightarrow CAC\bar{S}H_{12}$

   (Calcium Sulpho aluminate)

   - Responsible for flash setting
   - Gypsum added to control its reaction
   - Generates highest heat among all compounds

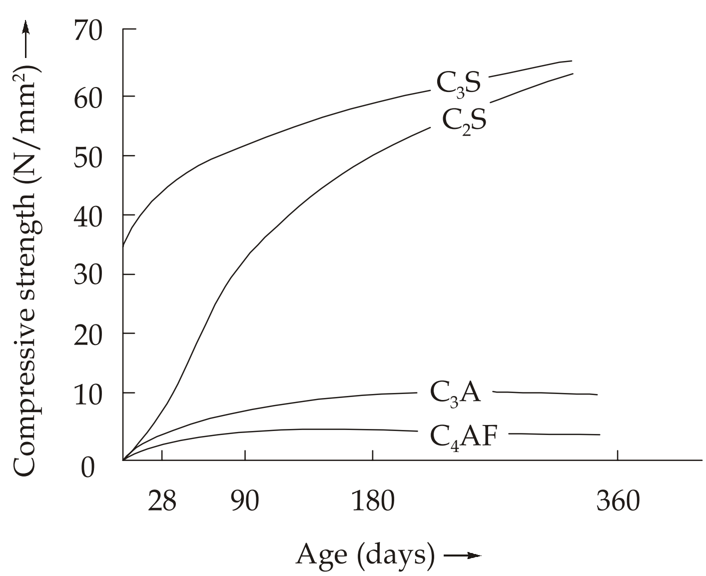
4. Tetracalcium Aluminoferrite (C_4AF):

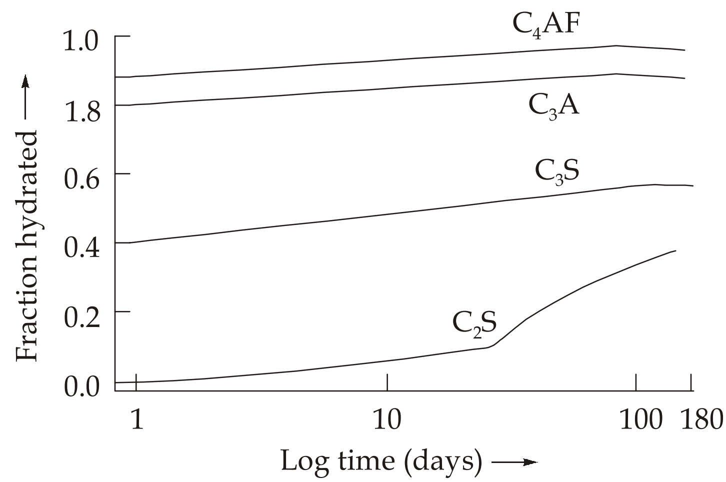
   $C_4AF + H_2O \rightarrow C_3AH_6 + CFH$

   - Minor role in strength
   - Generates less heat
   - Contributes to color and durability

Tobermorite: The naturally occurring mineral structure similar to C – S – H gel. It is the main contributor to the strength of hydrated cement.

Portlandite ($Ca(OH)_2$): Crystalline by-product of C_3S and C_2S hydration. Though it helps in maintaining pH, it has poor cementing value and is susceptible to leaching and chemical attack.





(ii)

For complete hydration of cement, water is required in two forms:

- **Bound Water:** This chemically combines with cement compounds during hydration. It is about 23% by weight of cement.
- **Gel Water:** This water is physically held within the gel pores formed in the hydrated cement paste. It is about 15% by weight of cement.

Hence, a total of around 38% water by weight of cement is required for full hydration and gel saturation. If the water-cement ratio is less than 0.38, full hydration may not occur. However, higher strength can still be achieved in such cases due to reduced porosity.

Q.3 (a) Solution:

(i)

1. **Batching:** Batching is the process of measuring concrete ingredients (cement, sand, aggregate, water) in required proportions before mixing. It can be done by weight or by volume. Accurate batching ensures uniformity, strength, and durability of concrete. Weight batching is preferred for precision in large projects.

   Precaution : Moisture variation in aggregates should be avoided as it can affect water-cement ratio.

2. **Mixing:** The objective of mixing is to coat the surface of all aggregate particles with cement paste, and to blend thoroughly all the ingredients of concrete into a uniform mass so as to produce uniform and workable concrete. It can be done either by hands or by using mechanical mixers.

   Precaution: Overmixing may lead to segregation so duration of mixing should not exceed specified time.

3. **Transportation:** Transportation involves moving of freshly mixed or green concrete. The concrete from the mixer should be transported to the point where it has to be

placed or deposited as rapidly as possible by a method which prevents segregation or loss of ingredients.

Precautions: Jerks and delays should be avoided while transporting concrete.

4. **Placing:** Placing refers to laying and compacting concrete immediately after mixing. It must be done within 30 minutes to avoid initial setting. Concrete should be placed in layers, avoiding segregation or loss of material. Shuttering should be clean and oiled before placing.

   Precaution: Concrete should not be dropped from height while placing.
5. **Compaction:** It is the process of removal of entrapped air from the concrete mass. It is performed to make the concrete impermeable enough to attain desired strength.

   Precaution: Vibration should be applied uniformly and only for the recommended duration to avoid displacement of aggregates and excess water rising to surface.
6. **Finishing:** Finishing gives the final appearance and texture to the concrete surface. It starts after the bleed water disappears, using floats and trowels. Good finishing ensures durability, skid resistance, and surface hardness, especially for slabs and pavements.

   Precaution: Finishing should not be started until the surface moisture film disappears.
7. **Curing:** Curing is the process of maintaining sufficient moisture and temperature in concrete to allow proper cement hydration. It should start soon after finishing and continue for 7-14 days. Curing increases strength, reduces shrinkage, and prevents cracking in concrete. Common methods include water spraying and wet coverings.

   Precaution: Curing water should be free from oils, acids and alkalis.

(ii)

Lime is both a sustainable and green building product. It has many green attributes as a building material when viewed from the perspective of building occupant– comfort and environmental performance. Sustainability is assessed through examination of limestone as a natural resource, energy requirements for lime production, and the carbon balance.

Lime is a low cost, natural material produced only through heating limestone. It does not contain or release toxic or harmful ingredients; in fact, it is likely to react with or absorb substances that are harmful in the built environment. Lime production is widely distributed just as limestone is. As a result, lime producers typically service a local market with minimal shipping distances. Lime can be an important component of masonry, stucco and plaster systems. These systems have following green attributes:

Optimisation of Energy Performance

Building wall systems that use lime provide high thermal mass to improve energy efficiency. The lime-based systems have thermal mass that reduces temperature fluctuations. The white colour of lime, utilised in mortars or whitewash, will produce a more reflective surface on the exterior of the building

Improvement in Indoor Environment Quality

Hydrated lime absorbs carbon dioxide and, in so doing, converts back to its original form, limestone and they can also be beneficial in reducing indoor air pollutants.

Building reuse - Materials and Resources

Lime-based mortars, stucco and plaster have proven durability that allows for reuse of existing walls, floors, and roofs in structures that contain these products.

Resource Reuse

Old mortar, stucco and plaster could be crushed and screened for use as an aggregate in mortar or stucco mixes

Q.3 (b) Solution:

(i)

A good building stone must possess specific physical, mechanical, and chemical properties to ensure durability, strength, and economy in construction. The following are the key characteristics:

1. **Appearance :** For face work, the stone should have a fine, compact texture and a uniform color. Light-colored stones are generally preferred as dark shades tend to fade with time. The stone should also be free from visible stratifications and undesirable patches.
2. **Structure :** A good stone should be uniform in texture and free from cavities, cracks, loose materials, or patches of soft or decomposed matter. A broken surface should appear crystalline and dense, without laminated or foliated planes.
3. **Strength :** The compressive strength of a good building stone should generally range from 60 to 200 N/mm^2. Stones should resist crushing, weathering, and external loads, especially in structural applications like load-bearing walls and dams.
4. **Weight :** The weight of a stone is an indicator of its density and porosity. For structural stability, heavier stones are preferred in retaining walls and dams, whereas lighter stones may be used in arches, domes, and vaults.
5. **Hardness :** Stones used for pavements, aprons of bridges, and flooring must be hard enough to resist abrasion and wear. Hardness is usually measured using the Mohs scale.
6. **Toughness :** Stones should have adequate toughness to resist impact and vibrations, especially in road work. It is determined by the amount of energy the stone can absorb before failure.
7. **Porosity and Water Absorption :** Stones should be less porous to prevent damage due to freezing and thawing. The permissible water absorption by volume is:

Sandstone, Limestone, Shale – up to 10%

Granite, Trap, Gneiss, Slate – up to 1%

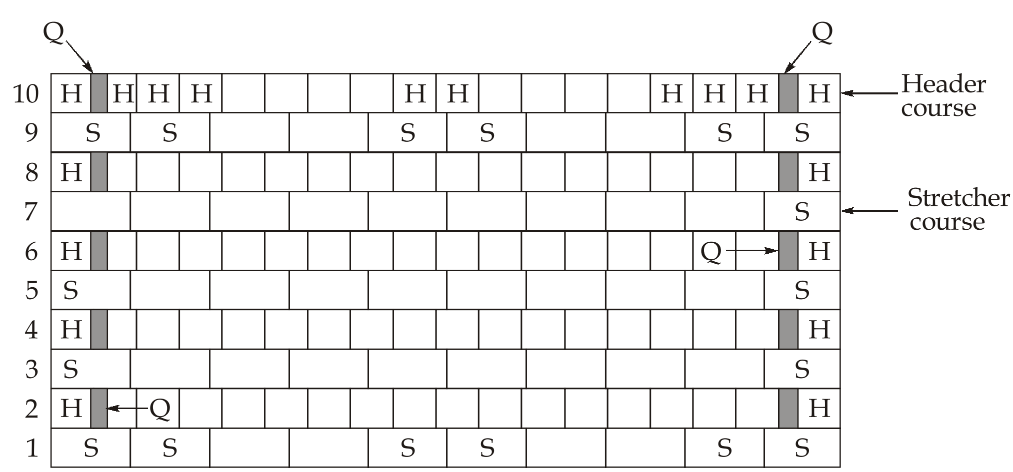
Quartzite – up to 3%

8. **Fire Resistance :** Good building stones should withstand high temperatures. Some stones like granite can resist fire up to 800°C, while limestone disintegrates above 575°C.
9. **Specific Gravity :** The specific gravity of building stones should lie between 2.4 to 2.8, indicating a dense and strong material.
10. **Durability and Weathering Resistance :** Stones should be able to resist the action of weather, moisture, and temperature changes. Stones from exposed faces and upper beds are usually less durable. Hence, durability is critical in external applications.
11. **Workability:** Stones should be workable so they can be easily cut, shaped, and dressed to required sizes without much wastage. However, excessive softness may reduce durability.
12. **Thermal Stability :** Stones should withstand minor thermal movements without cracking or spalling. Stones with homogeneous texture and stable mineral composition offer better thermal performance.

(ii)

(I) English Bond :

- This bond consists of alternate courses of headers and stretchers.
- In this arrangement, vertical joints in the header courses come over each other and the vertical joints in the stretcher courses are also in the same vertical line.
- For breaking of vertical joints in the successive courses, it is essential to place queen closer, after the first header in each header course.



S = Stretcher : H = Header : Q = Queen closer

ENGLISH BOND

- The following additional points should be noted in English bond construction:
  1. A header course should never start with a queen closer as it is liable to get displaced from this position.
  2. In the stretcher course, the stretchers should have a minimum lap of $1/4^{th}$ of their length over the headers.
  3. In walls having thickness equal to an odd number of half brick, i.e., $1\frac{1}{2}$ brick thick walls or $2\frac{1}{2}$ brick thick walls and so on, the same course will show stretchers on one face and headers on the other.

(II) Flemish Bond

- In this arrangement of bonding brick work, each course consists of alternate headers and stretchers.
- The alternate headers of each course are centered over the stretchers in the course below.

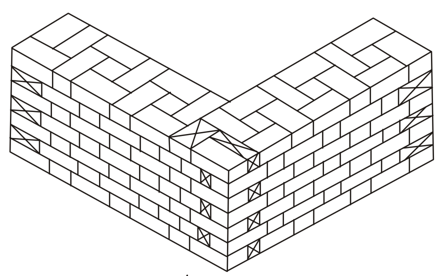


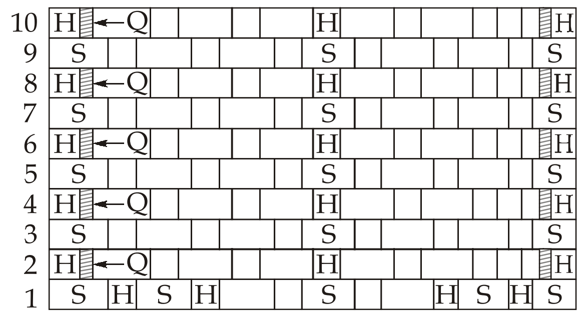
Fig. *Flemish Bond*

- Every alternate course starts with a header at the corner.
- For breaking the vertical joints in the successive courses, closers are inserted in alternate courses next to the quoin header.
- In walls having thickness equal to odd number of half bricks, bats are essentially used to achieve the bond.
- Flemish bond is further divided into two different types viz. Single Flemish bond and Double Flemish bond.

(III) Double Flemish Bond

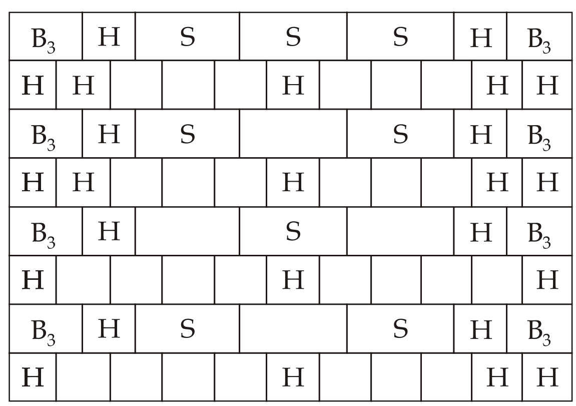
- In this system of bonding brick work, each course presents the same appearance both in the front and back elevations.
- Every course consists of headers and stretchers laid alternately.

- This type of bond is best suited from considerations of economy and appearance.
- It enables the one brick thick wall to have flush and uniform faces on both the sides.



DOUBLE FLEMISH BOND (ELEVATION)

(III) Dutch bond: This bond is a modification of the old English cross bond and consists of alternate courses of headers and stretchers.



DUTCH BOND ($B_3 \rightarrow 3/4$ Bat)

Q.3 (c) Solution:

(i)

(I) Purpose of Plastering:

The plastering of building parts is provided for the following purposes:

1. To provide an even, smooth and durable finished surface.
2. To improve the appearance of building.
3. To protect the surface from the effects of weathering agents *i.e.* water, temperature, etc.
4. To conceal the defective workmanship and inferior quality of materials used in construction.
5. To provide a smooth base for colour washing, painting or distempering.
6. To protect the internal surfaces against dust, dust and vermin nuisance
7. To protect porous materials and faulty joints.

(II) Types of Plaster

Following are the types of plaster:

1. **Lime plaster.** Lime mortar contains equal volume of lime and sand. The mixture is finely ground in a mortar mill.
2. **Cement plaster.** Cement mortar contains one part of cement and 3 to 4 parts of clean, coarse and angular sand. The mixture is thoroughly mixed in dry conditions on a watertight platform.
3. **Stucco plaster.** Stucco plaster is a decorative type of plaster with elegant finish like that of marble.
4. **Water proof plaster.** It consists of one part of cement, two parts of sand and pulverised alum 12 kg per cubic metre of sand. Water containing 75 g of soft soap per litre is used for preparing the mortar.

(III) Defects in Plastering:

Defects in plastering are:

1. Cracks,
2. Efflorescence,
3. Blistering,
4. Falling off.

(IV) Characteristics of an ideal plaster

The following are the essential characteristics of an ideal plaster:

(i) It should adhere firmly to the surface.

(ii) It should not experience any change in volume while drying and setting.

(iii) It should resist the effects of wheathering agents.

(iv) It should offer good resistance against fire.

(v) It should provide smooth, washable and non-absorbent surface.

(vi) It should provide a surface of good decorative look.

(ii)

On full hydration,

$$\text{Volume of gel} = C \times 0.319 \times 2.06 = 0.657\,C$$

$$\text{Space available} = C \times 0.319 + W_o$$

$$\therefore \quad \text{Gel space ratio } (x) = \frac{0.657C}{0.319C + W_o}$$

$$W_o = 450 \times 0.48 = 216 \text{ g}$$

$$\therefore \quad \text{Gel space ratio } (x) = \frac{0.657 \times 450}{0.319 \times 450 + 216}$$

$$= 0.822$$

Theoretical Strength, $S = 240\, x^3 = 240 \times (0.822)^3$

$= 133.3 \text{ N/mm}^2$

On 75% hydration,

$$\text{Get space ratio } (x) = \frac{0.657C\alpha}{0.319C\alpha + w_o} = \frac{0.657 \times 450 \times 0.75}{0.319 \times 450 \times 0.75 + 216} = 0.685$$

Theoretical strength, $S = 240\, x^3 = 240 \times (0.685)^3$

$= 77.14 \text{ N/mm}^2$

Q.4 (a) Solution:

(i)

Classification Based on Service Life (Indian Standard Classification):

IS: 3639-1966 has classified timber into three classes based on its service life as:

1. **Class I:** Natural durable heartwood timber having average life of 120 months or more,
2. **Class II:** Natural durable heartwood timber having average life of 60 months or more, but less than months.
3. **Class III:** Wood timber having average life less than 60 months.

Classification Based on Availability

IS: 339-1963 has grouped the timber into three grades based on its availability as follows:

1. X: Most common grade–1415 m^3 (1000 tonnes) or more per year
2. Y: Common grade–335 m^3 (250 tonnes) to 1415 m^3 (1000 tonnes) per year
3. Z: Less common grade–less than 335 m^3 (250 tonnes) per year

Classification Based on the Strength

Based on its mechanical properties, timber may be classified as average, good and very good depending upon its modulus of elasticity, E_t and modulus of rupture, ρ_t as follows:

1. Average timber: E_t from 6600 to 9800 MPa and ρ_t from 8.5 to 12 MPa
2. Good timber: E_t from 9800 to 12600 MPa and ρ_t from 12 to 18 MPa
3. Very good timber: E_t > 12600 MPa and ρ_t > 18 MPa

Classification Based on the Seasoning Properties

Based on its seasoning properties, timber may be classified into three categories as follows:

Nonrefractory Timbers: Those which can be satisfactorily seasoned in open without developing any defects. Examples of timbers falling under this category are salai, semul, etc.

Moderately Refractory Timbers: Those which can be seasoned with suitable precautions against rapid drying. Examples of timbers falling under this category are: teak, sheesham, tun, semul, etc.

Eminently Refractory Timbers: Those which require suitable precautions during seasoning. Heavy structural timbers like sal fall under this category.

(ii)

Advantages of aluminium as a building material are as follows:

High Corrosion Resistance: Due to high corrosion resistance aluminium is preferred over steel in a number of applications, e.g., for tall buildings and the buildings located near sea shores.

High Strength-to-Weight Ratio: Structural components made from aluminium and its alloys are vital to the aerospace industry and very important in other areas of transportation like automobiles, aircraft, trucks, railway cars, marine vessels, bicycles, etc.

Aluminium is extensively used in roofing sheets which are relatively lightweight. They are easy to transport without damage, easy to install, require minimum supporting structure, permit large spans, and resistant to wind and water.

Resistant to Biological Hazards: Unlike wood, aluminium is safe against moth and insect attack (white ants and borers), and can be advantageously used for door and window frames.

Low Maintenance: Aluminium part requires no painting and very little maintenance as it is self-healing and self-maintaining.

Aesthetic Appearance: Aluminium is considered as an architectural material having good aesthetic value. It can be anodised or powder coated to give various colours and shades.

Capacity to Withstand Low Temperatures: Aluminium can withstand sub-zero temperatures whereas structural steel becomes brittle and does not perform properly. Although the coefficient of expansion of aluminium is 1.9 times that of steel, but its modulus of elasticity is one-third of steel. Thus, thermal movements in aluminium cause considerably less stress than that in steel. Aluminium has been successfully used in base camps in Antarctica expeditions.

Ease of Fabrication and Assembly: Aluminium sections can be manufactured by extrusion to suit specific requirements. Even complicated sections can be extruded or built-up with very little additional cost. The sections generally extruded are for sliding windows, doors, facade for tall buildings, etc. Being lightweight they are easy to handle and assemble at the site.

Prefabricated framed construction systems of steel or aluminium are assembled extremely quickly. With strong connections, such systems can be very resistant to earthquake and hurricane destruction.

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Air tightness: Extrusion process allows aluminium sections to be made with very low tolerance, enabling the building components to be fabricated with precision to be airtight. This is an important consideration for the windows, doors, facade for tall and air-conditioned buildings.

Good Noise Control: Aluminium parts provide good noise control because of its excellent reflectivity of sound. It also reflects electromagnetic waves.

Good Heat and Light Reflectivity: A thin layer of aluminium deposited onto a flat surface by physical/chemical vapour deposition or other chemical means forms optical coatings and mirrors. When so deposited, a fresh, pure aluminium film serves as a good reflector, reflecting approximately 92 per cent of visible light.

Recyclability: The recycling rate for aluminium is very high because of its high scrap value and the preservation of all its chemical and physical properties. The amount of energy used to produce aluminium from ore is highest among all nonferrous metals. Thus it is energy-efficient to reprocess the aluminium.

Easy to Transport: Aluminium is easy to transport because of its light weight.

High Reflectivity: Aluminium roofs absorb less radiation heat as aluminium has good reflectivity. It is an ideal material for roofing of workshop sheds. Aluminium paints and films are used for thermal insulation of roofs, and so on.

High Electrical Conductivity: Aluminium wires are used for high voltage electric distribution. However, aluminium tends to oxidise in contact with the copper; it is a better material to be used in small sizes in house wiring with appropriate fixtures.

Q.4 (b) Solution:

(i)

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

Accelerators: Normally reduce the setting time, accelerate the rate of hydration of cement and consequently the rate of gain of strength. The examples of accelerators are sulphates with an exception of calcium sulphate, alkali carbonates, aluminates and silicates, aluminium chloride, calcium chloride, sodium chloride, sodium and potassium hydroxides, calcium formate, formaldehyde.

Some substances may act as accelerators or as retarders according to the proportion added. For example, $CaCl_2$ when added up to 2% by weight of cement acts as accelerator, but on increasing the proportion, it acts as retarder and leads to flash set. Similarly, triethanolamine when added in proportion less than 0.06% by weight of cement acts as an accelerator but acts as retarder if the dosage is increased. $CaCl_2$

and NaCl are very useful to permit concreting in very cold weather (–23°C). These lower the temperature at which freezing takes place, help to keep the mixture warm by accelerating the generation of heat, and increase the ability of the concrete to resist frost by speeding up the rate of gain of strength.

Retarders: 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. Retarders increase the compressive strength under freezing and thawing. Calcium sulphate, sugar, starch, cellulose, ammonium, ferrous and ferric chlorides, sodium hexa-meta-phosphate, lignosulphonic acid and their salts, carbohydrates, hydrocarboxylic acids and their salts are a few examples of retarders. The use of $CaSO_4$ as retarder prevents flash set of cement. An addition of 0.2% sugar by mass retards the hydration of cement to such an extent that the final set may not take place even for 72 hours. It has also been found that an addition of 0.1% sugar by mass of cement raises the strength of cement at 3 days and increases the 28 days strength by 30%. Retarders are very important in the situations where grouting is to be done for the voids behind the concrete arch, tunnel lining, etc. These also ensure a better bond between successive lifts in concrete constructions. These are very useful, particularly in composite construction where the steel rolled-sections have to carry the load of concrete before the latter is capable of acting as a compression member.

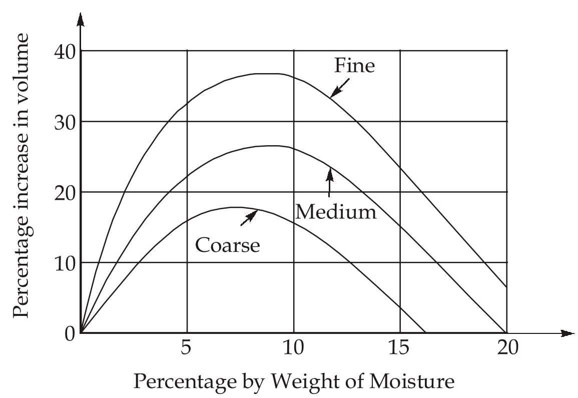
Also, with retarders, the concrete can be mixed by using hot water or injecting steam and it has been found that 28 days strength of concrete is not affected as is the case with normal accelerated curing.

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

(ii)

The presence of free moisture in sand increases the volume of sand which is known as bulking of sand. Free moisture forms a film around each sand particle. This film of moisture exerts what is known as surface tension which keeps the neighboring particles away from it. Similarly, the force exerted by surface tension keeps every particle away from each other. Therefore, no point contact is possible between the particles. This causes bulking of the volume. The extent of surface tension and consequently how far the adjacent particles are kept away will depend upon the percentage of moisture content and the particle size of the fine aggregate. It is interesting to note that the bulking increases with the increase in moisture content upto a certain limit and beyond that with further increase in the moisture content, it results in the decrease in volume and at a moisture content representing saturation point, the fine aggregate shows no bulking. It can be seen from the figure below that fine sand bulks more and coarse sand bulks less. From this it follows that the coarse aggregate also bulks but the bulking is so little that it is always neglected.

The graph below shows the variation of percentage increase in volume of sand with moisture content.



Due to the bulking, fine aggregates show completely unrealistic volume. Thus, the extent of bulking can be estimated by a simple field test. A sample of moist fine aggregate is filled into a measuring cylinder in the normal manner. The level is noted down say h_1. Pour water in the measuring cylinder and completely inundate the sand and shake it. Since the volume of the saturated sand is same as that of dry sand, the inundated sand completely offsets the bulking effects. The level of the sand is again noted down say h_2. Then $h_1 - h_2$ shows the bulking of the sample of sand under test.

$$\text{Percent of bulking} = \left(\frac{h_1 - h_2}{h_2}\right) \times 100$$

Q.4 (c) Solution:

(i)

Engineering or Mechanical Properties of Glass as a Building Material:

1. Glass is a hard and tough but brittle material, and does not deform plastically. It fails in tension regardless of the nature of loading. The theoretical tensile strength of glass is about 7 GPa but failure occurs at stresses much lower than that, because of surface imperfections.

2. Typically, an untreated, plain annealed plate glass fails at tensile stress around 70 to 140 MPa. However, although the actual strength of glass is dependent upon the extent, type and depth of surface imperfections, there is considerable variation in failure stress of any individual piece of glass.
3. The strength of glass is improved by heat-treatment. Simple heat strengthening of the outer surface of the glass may increase its strength by a factor of two. Full tempering of the glass generally increases its strength three to five times.
4. Annealed glass typically breaks into large jagged pieces with shades hanging from the frame. Wired glass breaks similarly to annealed glass, however more pieces of glass stay in place, because of the wires. Tempered glass of a thickness common in windows will probably not break under the design loads, but if it does, it disintegrates into very small granules. Laminated glass will typically remain intact, because of the plastic interlayer, although it may be badly cracked.
5. The glass disintegrates easily under fire and fall out of its frame, thus creating an opening in the fire separation, which would allow the fire to spread. The wires in wired glass prevent glass shades from falling out of glass panels, and hold glass together in fire applications and slow spreading of fire.
6. It is possible to make glass lighter than cork or cotton or stronger than steel through the application of advanced technologies. Some forms of glass are bulletproof.

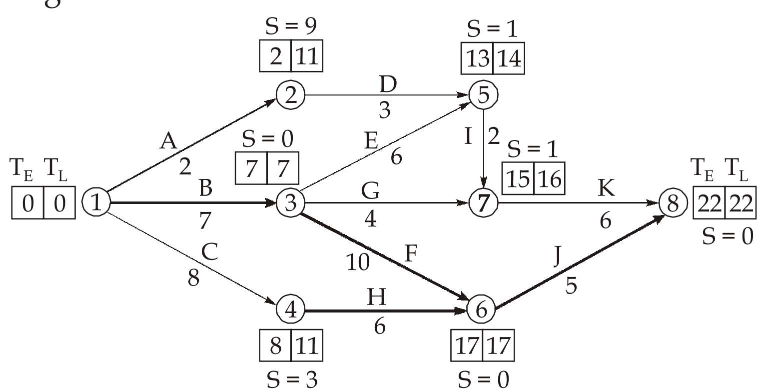
(ii)

S. No.	Thermoplastic Resins	Thermosetting Resins
1.	They are formed by addition polymerization only	They are formed by condensation polymerization.
2.	They consist of long-chain linear polymers with negligible cross-links.	They have three-dimensional network structure.
3.	They soften on heating readily, because secondary force between the individual chain can break easily by heat or pressure or both	Their cross-links and bonds retain their strength on heating and, therefore, they do not soften on heating. On prolonged heating, however, charring of polymers is caused.
4.	By reheating to a suitable temperature, they can be softened, reshaped and thus reused.	They retain their shape and structure, even on heating. Hence they cannot be reshaped and reused.
5.	They are usually soft, weak and less brittle.	They are usually hard, strong and more brittle.
6.	They can be reclaimed from wastes.	They cannot be reclaimed from wastes.
7.	They are usually soluble in some organic solvents.	Due to strong bonds and cross-links, they are insoluble

Section B : Planning and Management + Tunnelling

Q.5 (a) Solution:

The network of the given activities is shown in below :



The earliest event time and latest event time have been calculated as below :

$$T_E^j = T_E^i + t^t$$

$$T_L^i = T_L^i + t^t$$

We also know that EST = T_E^i; EFT = $T_E^i + t^t$

LST = $T_L^j - t^t$; LFT = T_L^j

Total float, F_T = LFT – EFT = LST – EST

Free float, F_F = EST of successor activity – EFT of present activity

= $F_T - S_i$

Independent float, $F_{ID} = F_F - S_i$

The values of activity times, total float, free float and independent float are tabulated below:

Activity	Duration	EST	EFT	LST	LFT	F_T	F_F	F_{ID}	Remarks
A	2	0	2	9	11	9	0	0	
B	7	0	7	0	7	0	0	0	Critical
C	8	0	8	3	11	3	0	0	
D	3	2	5	11	14	9	8	–1	
E	6	7	13	8	14	1	0	0	
F	10	7	17	7	17	0	0	0	Critical
G	4	7	11	12	16	5	4	4	
H	6	8	14	11	17	3	3	0	
I	2	13	15	14	16	1	0	–1	
J	5	17	22	17	22	0	0	0	Critical
K	6	15	21	16	22	1	1	0	

The activities on the critical path are those activities that have total float (F_T) equal to zero. Thus $B - F - J$ will be the critical path.

Q.5 (b) Solution:

(i) Liquidated damage :

It is fixed stipulated sum of penalty charged on to the contractor for exceeding period taken for the completion of the work than that specified in the contract.

Delay in project means delay in getting back return on investment which will also affect the financial viability of the project. To ensure that the project implementation is carried out as per the original schedule, liquidated damage clause is incorporated in the contracts.

For delay on monthly, weekly, or even on daily basis for very critical projects, there will be deduction of payment from running account bill (RA bill) for every month/week/day of delay.

(ii) Tender drawing and working drawing

Tender drawing:

Tender drawings are the set of engineering drawings that depict first evidence of the project scheme regarding type and quality of the work involved and hence these are prepared by engineers with great care and with particular attention to drafting and presentation for clarity and ease of understanding. The contractor is concerned with the clarity and logical expression of engineering details.

In small projects, tender drawings, contract drawings, working drawings and even the completion drawings may be the same. However, in large projects these drawings are prepared at various stages of execution.

Working drawing:

The working drawing fill the gaps in constructional details not reflected in tender drawings.

Working drawings are used for working, manufacturing, constructing or building purposes and must therefore represent the engineer's final decisions and design details as changes in drawings hereafter can be expensive, particularly when construction work has already commenced.

(iii) Percentage rate contract:

In this form of contract, tender documents contain the analysed schedule of rates for each item, in addition to the detailed estimated quantities expected in the execution of the works. Thus, an estimate of the total value of the work is clearly available to the contractor.

Now, the contractor works out his rates for the items and arrives at his total price, which is converted to a percentage by which his amount differs from the estimate given. This percentage is submitted as a quotation by the contractor.

This method requires detailed analysis of the rates and is usually adopted for government contracts or inlarge organisations.

(iv) Scaffolding:

When the height of wall or column or other structural member of a building exceeds about 1.5 m, temporary structures are needed to support the platform over which the workmen can stand and carry on the construction. These temporary structure, constructed very close to the wall, is in the form of timber or steel framework, commonly called scaffolding.

The scaffolding should be strong and stable to support both workmen and construction material placed on the platform supported by the scaffolding.

The height of the scaffolding goes on increasing as the height of construction increases.

Such scaffolding is also needed for the repairs or even demolition of a building.

(v) Turnkey contracts:

In such type of contracts, all the activities related to the establishment of the facility are handed over to the contracting agency and the owner simply 'turn the key' at completion to take over the facility.

All activities related to surveying, drawings and specifications, design, project planning, construction and test operation are entrusted to one large contracting organisation, which may break the activities down and engage other agencies to carry out specific jobs.

Such contracts have been found useful especially in projects involving a combination of civil, electrical, mechanical, chemical and mining engineering and are seen typically in design and construction of industrial complexes including petrochemical plants and nuclear power stations.

Q.5 (c) Solution:

(i)

Slack :

Slack may simply be defined as the difference between the latest allowable time and the earliest expected time of an event. The difference between the two times indicates the range between which the occurrence time of an event can vary.

$$\therefore \quad S = T_L - T_E$$

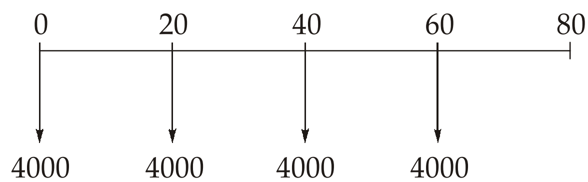
Where S is the slack for any event, T_E is the earliest expected time of an event and T_L is the latest allowable time of an event.

Negative slack is obtained when the scheduled completion time, T_S (and hence T_L) is less than the earliest expected time of completion (T_E). It is an indication of a behind of schedule condition (lack of resources).

(ii)

Overall present worth on the basis of building's life (80 yrs) is to be calculated for both choices.

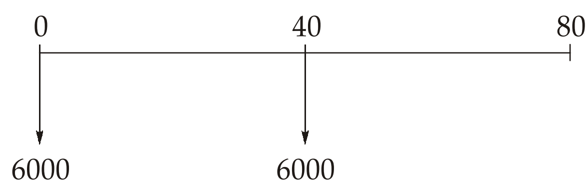
Choice A:



$$P_{A(80)} = 4000 + 4000\left[\frac{P}{F}, 5\%, 20\right] + 4000\left[\frac{P}{F}, 5\%, 40\right] + 4000\left[\frac{P}{F}, 5\%, 60\right]$$

$$= 4000\,[1 + (1.05)^{-20} + (1.05)^{-40} + (1.05)^{-60}] = \text{Rs. } 6289.88$$

Choice B:



$$P_{B(80)} = 6000 + 6000\left[\frac{P}{F}, 5\%, 40\right]$$

$$= 6000 + 6000\left[\frac{1}{(1.05)^{40}}\right]$$

$$= 6000\,[1 + (1.05)^{-40}] = \text{Rs. } 6852.27$$

$\because \quad P_{A(80)} < P_{B(80)}$

$\therefore$ Choice *A* is more economical.

Q.5 (d) Solution:

(i)

The probability factor is given by:

$$Z = \frac{T_s - T_E}{\sigma}$$

where, T_E = 15 months and σ = 3 months.

(i) Given; T_s = 15 months

$\therefore \quad Z = \frac{15 - 15}{3} = 0$

For Z = 0; Probability = 50%

(ii) Given; $T_s = 21$ months

$$\therefore \quad Z = \frac{21 - 15}{3} = 2$$

For $Z = 2$, Probability = 97.72%

(iii) Given: $T_s = 12$ months

$$\therefore \quad Z = \frac{12 - 15}{3} = -1$$

For $Z = -1$, Probability = 15.87%

(ii)

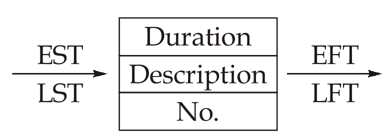
Advantages of A-O-N over A-O-A:

In A-O-A network, activities are connected occurring to finish and start logic i.e. an activity starts only after its preceding activity is accomplished, but in reality, a certain overlapping of time between the adjoining activities is suitable.

A-O-N network whereas incorporates the concept of delays (lags) which depicts the relationship of various start and finish activities. They represent a real time and realistic plan which shows the dependency and interrelationship of various activities in a much better way than A-O-A network.

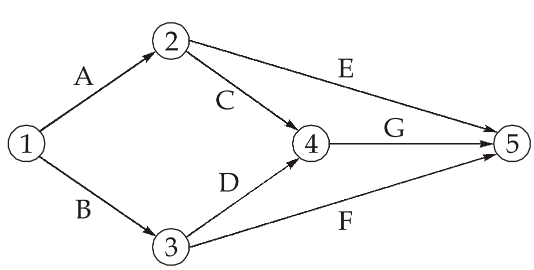
Thus A-O-N is best suited for complex type of project and is also known as Precedence Network Analysis (PNA) and Precedence Diagramming Method (PDM).

Each activity in A-O-N network is represented by a rectangular or a square box. Generally, the activity descriptions is written in middle portion of the node box. The activity data in the box also includes duration, activity timings and activity number. Presentation is shown below.



This system is self sufficient as it contains all activities times (EST, LST, EFT, LFT) on the diagram itself. This facilitates efficient scheduling and controlling.

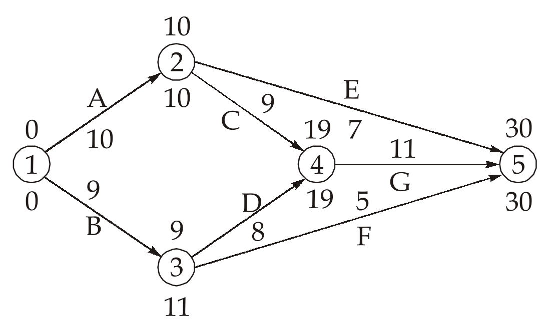
Q.5 (e) Solution:



A – C – G critical path

Activity	Time estimates (days)	Expected time (days)	Standard deviation (days)
A	6 – 9 – 18	10	2
B	5 – 8 – 17	9	2
C	4 – 7 – 22	9	3
D	4 – 7 – 16	8	2
E	4 – 7 – 10	7	1
F	2 – 5 – 8	5	1
G	4 – 10 – 22	11	3

Now the network diagram is shown below.



Critical path is A–C–G.

Expected time for the completion of project = 30 days.

Standard deviation along critical path (σ) = $\sqrt{\sigma_A^2 + \sigma_C^2 + \sigma_G^2}$

$$= \sqrt{2^2 + 3^2 + 3^2} = 4.6904$$

Scheduled time = 35 days

$$\therefore \quad Z = \frac{T_s - T_E}{\sigma} = \frac{35-30}{4.6904} = 1.066$$

Corresponding probability of completion

$$= 84.13 + \frac{(86.43-84.13)}{(1.1-1.0)}(1.066-1.0) = 85.648\%$$

Q.6 (a) Solution:

(i) **Dragline :** Since the basic character of this machine is dragging the bucket against the material to be dug and thus, it is called as dragline. A dragline is used to excavate the earth and load it into hauling units such as trucks or tractor pulled wagons or to deposit it into dams/embankments or spoil banks near the pit from which it is excavated.

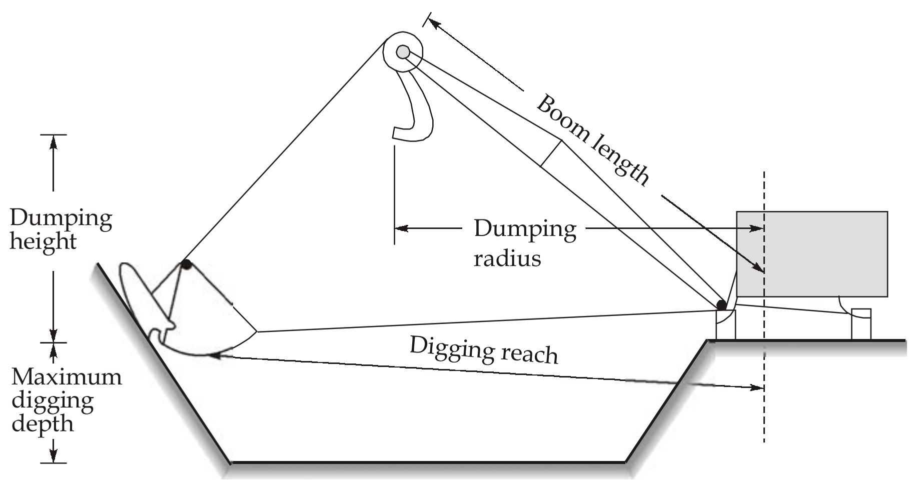
Draglines
- Crawler mounted dragline
- Wheel-mounted (self propelled dragline)
- Truck-mounted dragline

Advantages:

- A dragline is an excellent machine for excavating trenches without shearing.
- A dragline usually does not have to go into a pit or hole for excavating the earth. It may operate on natural firm ground.

  Therefore, it is more useful when earth is required to be removed from ditch, canal or pit containing water.

(ii)



Dragline

(iii) Factors affecting output of a dragline:

The output of a dragline is expressed in cubic metre/hour bank measure. The following factors affect the output:

- Class of material
- Depth of cut
- Angle of swing
- Size and type of bucket
- Job conditions
- Management conditions
- Method of disposal or loading trucks

- Size of hauling unit used
- Skill of operator
- Physical conditions of machine

Q.6 (b) Solution:

(i)

Quantity of brick ballast to be made = $1m^3$

Quantity of overburnt bricks used = $1.1m^3$

Cost of overburnt bricks = Rs. $250/m^3$

Labour cost = Rs. 19/head/day

Labour cost analysis:

∴ For 3 cum of brick ballast preparation;

Expenditure required = Labour cost (4 No. of labour days for 3 m^3 of ballast)

= 19 × 4 = Rs. 76

∴ For 1 m^3 of ballast preparation labour cost = $\frac{76}{3}$ = Rs. 25.33

Material cost analysis:

1.1 m^3 of overburnt bricks produces 1 m^3 brick ballast

Cost of $1m^3$ overburnt bricks = Rs. 250

∴ Cost required for making $1m^3$ brick ballast

= Rs. 250 × 1.1 = Rs. 275

∴ Total cost incurred for making $1m^3$ of brick ballast

= Labour cost required + Material cost required

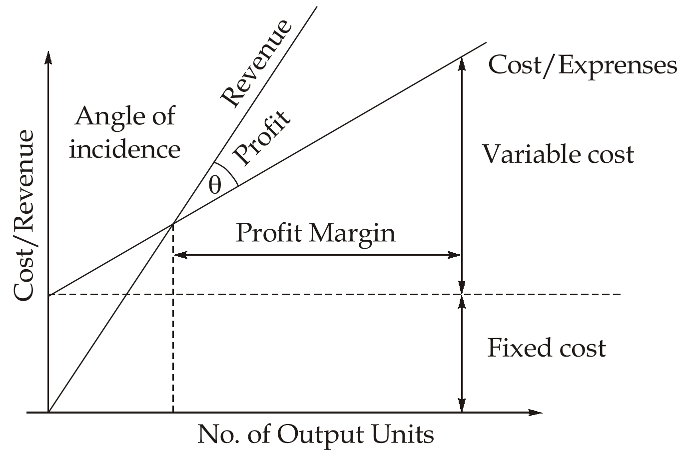
= 25.33 + 275

= Rs. 300.33

(ii)

- Break even Analysis is a graphical representation of the relationship between cost and revenue for all possible volumes of output.
- Break even analysis is basically done to find out the point at which, total revenue equals total cost and profit potential under varying conditions of output and cost.
- Break even point is therefore a point at which neither a profit nor a loss has incurred.

- Sometimes it is called as Cost-Volume-profit studies.



Uses of break even analysis:

1. Suitable for business firm to study cost revenue relationship.
2. Useful in making engineering decisions.
3. Useful in selection of favourable option of business.
4. Possibility of profit is determined for any rate of production.
5. It shows weather business is good or bad by angle of incidence. Greater the angle of incidence means more profit margin and we know that profit margin should be more for good business.

Limitations of break even analysis:

1. Break even analysis is suitable for small business.
2. It provides a static picture whereas business processes are dynamic in nature because the market conditions do not remains constant.
3. Revenue line may not be always a straight line.
4. Analysis of break even becomes difficult when company produces different/ variety of products.
5. Cost and revenue are related only with number of units produced. They have no relation with the time.

Q.6 (c) Solution:

(i) $$\text{Time required (per phase)} = \frac{(\text{No. of passes}) \times (\text{Distance per pass(kms)})}{(\text{Average speed (km/h)}) \times \text{Efficiency factor}}$$

$$\text{Number of passes} = 20$$

$$\text{Distance per pass} = 30 \text{ km (in each phase)}$$

$$\text{Average speed} = \frac{5\times2+6\times2+7\times2+9\times2+6\times2+8\times2+9\times2+11\times2+11\times2+8\times2}{20}$$

$$= 8 \text{ kmph}$$

$$\text{Efficiency factor} = \text{Operating efficiency} \times \text{Mechanical efficiency}$$

$$= 0.7 \times 0.85 = 0.595$$

$$\therefore \quad \text{Time required (per phase)} = \frac{20\times30}{8\times0.595} = 126 \text{ hours}$$

Time required for both the phases = 126 × 2 = 252 hours

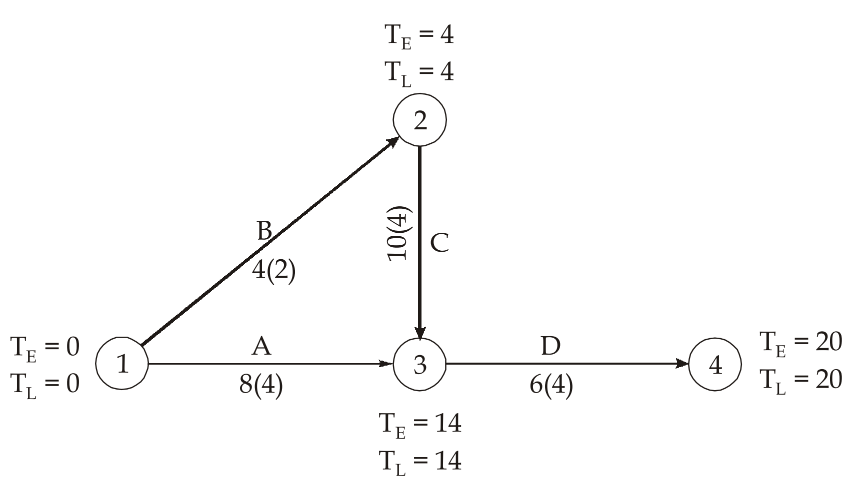
(ii)

The typical sequence of operations involved in tunnel construction is as follows:

1. Setting up and drilling.
2. Loading holes with explosives and firing them.
3. Ventilations and removing the dust after explosion.
4. Loading and hauling muck.
5. Removing ground water if necessity arises.
6. Erecting supports for sides and roof if necessary.
7. Placing reinforcement.
8. Placing concrete lining.

Q.7 (a) Solution:

Network Diagram:



Critical path = 1 – 2 – 3 – 4

Cost slope

Activity	Normal		Crash		Cost Slope		
	Time	Cost (Rs.)	Time	Cost (Rs.)	ΔC	Δt	$\Delta C/\Delta t$
A	8	6000	4	12000	6000	4	1500
B	4	2000	2	14000	12000	2	6000
C	10	4000	4	8000	4000	6	666.67
D	6	4000	4	8000	4000	2	2000

Normal cost at normal project duration

Normal project duration = 20 days

Direct cost = 6000 + 2000 + 4000 + 4000 = Rs. 16000

Indirect cost = 20 × 1000 = Rs. 20000

∴ Total cost = 16000 + 20000 = Rs. 36000

First stage crashing

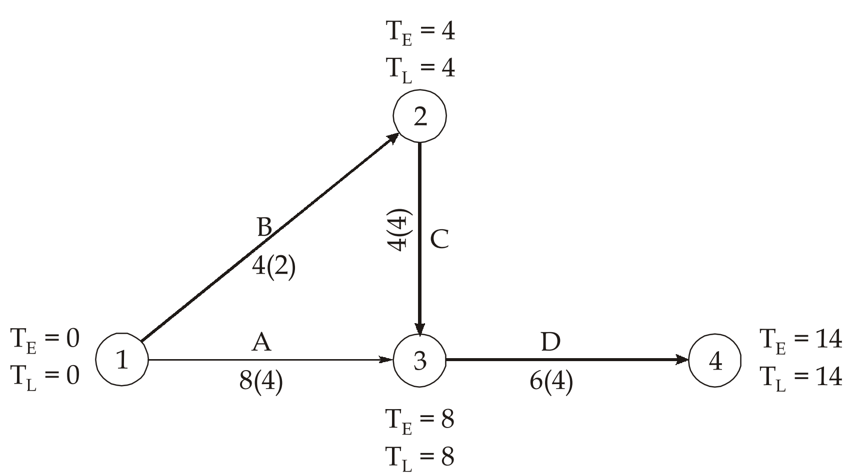
We can observe that among critical activities, activity *C* has minimum cost slope i.e. 666.67 and has crashing potential of 6 days. It can be crashed by 6 day without affecting other parallel activities.

New project duration = 20 – 6 = 14 days.

Direct cost = 16000 + 6 × 666.67 = Rs. 20000

Indirect cost = 14 × 1000 = Rs. 14000

∴ Total cost = 20000 + 14000 = Rs. 34000



Second stage crashing

We can observe that, now we have two critical paths A-D and B-C-D. Therefore we have to check various alternatives of combinations of cost slope

(i) Cost slope of B + Cost slope of A = 6000 + 1500 = 7500

(ii) Cost slope of D = 2000

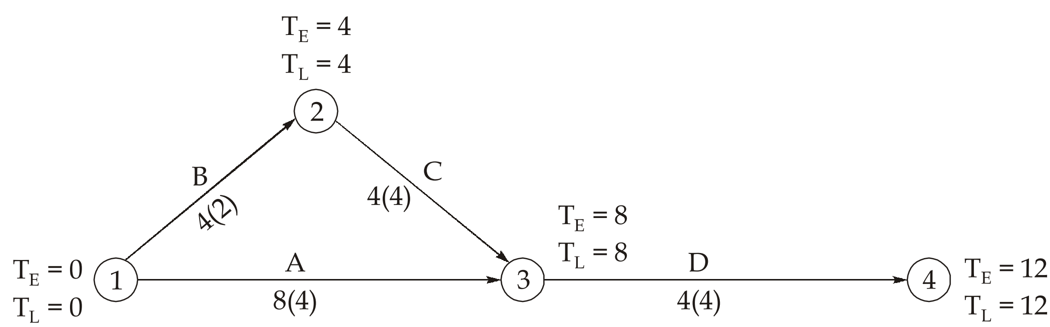
∴ Cost slope of activity D is minimum, therefore it can be crashed for its complete crashing potential that is 2 days.

∴ New project duration = 14 – 2 = 12 days

Direct cost = 20000 + 2 × 2000 = Rs. 24000

Indirect cost = 12 × 1000 = Rs. 12000

∴ Total cost = 24000 + 12000 = Rs. 36000



Third stage crashing

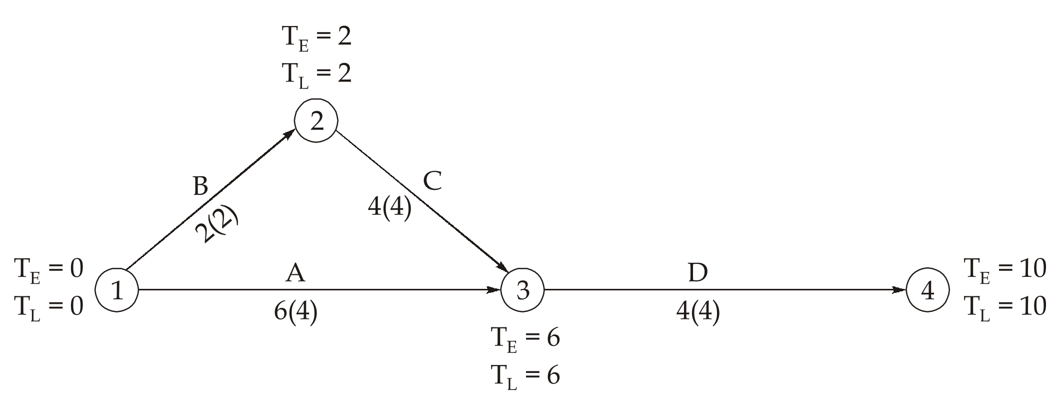
Now we can crash activity A and B simultaneously by 2 days. As these are parallel activities and crashing potential of activity B will get expired.

∴ New project duration = 12 – 2 = 10 days.

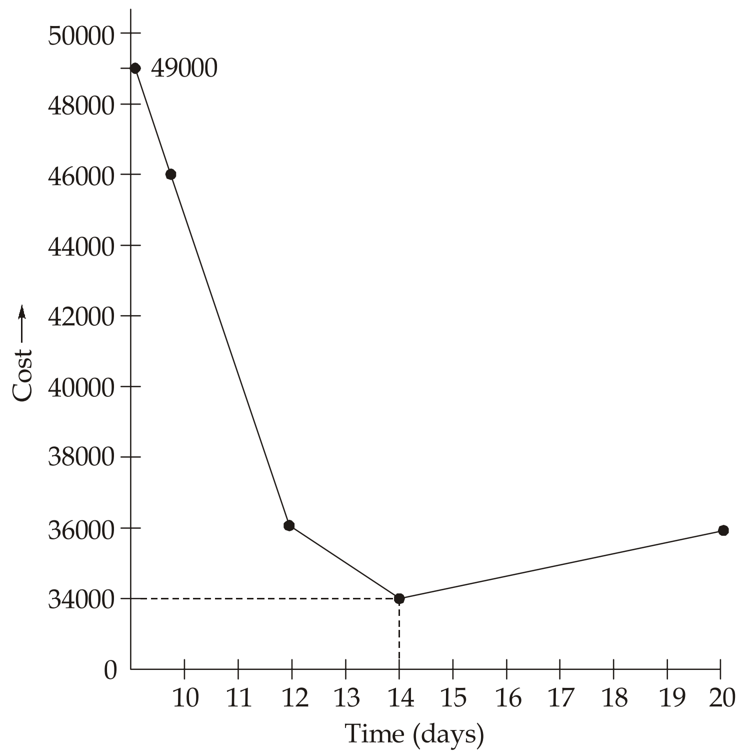
Direct cost = 24000 + 7500 × 2 = Rs. 39000

Indirect cost = 10 × 1000 = Rs. 10000

Total cost = 39000 + 10000 = Rs. 49000



Total Cost Curve:



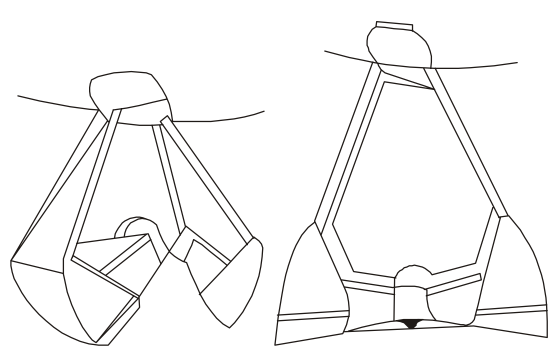
$\therefore$ Optimum project duration = 14 days

Optimum project cost = Rs. 34000

Q.7 (b) Solution:

(i)

1. **Clamshell:** It is a machine having most of the characteristics of dragline and crane in common. Digging is done like a dragline and once the bucket is filled, it works like a crane. Clamshell is best suited for lifting the materials vertically.



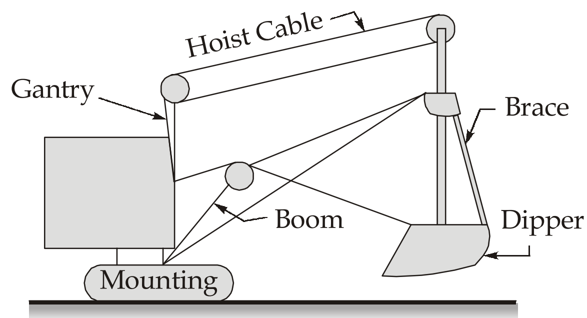
Clamshell

Clamshell bucket

The bucket can be attached to shovel-crane units or at the beam of a dragline.

It is primarily used for handling loose material such as sand, gravel etc. and for removing materials from coffer dams, pier foundations etc.

2. **Hoe:**



Hoe

Hoe is an excavating equipment of the power shovel group. It is generally used to excavate below the natural surface of the ground on which the machine rests, like digging trenches, footings or basements and general grading work which required precise control of depths.

Similarly, used for operating on close range work and dump into trucks, penetrates easily into toughest material to be dug.

(ii)

Revised estimate: It is a detailed estimate for the revised quantities and rates of items of original estimate. The structural nature of the revised estimate must not be changed from the originally approved estimate.

Revised estimates are prepared under following circumstances:

- When a sanctioned estimate is likely to exceed more than 10% due to any reasons except important structural alterations.
- When there are material deviations from the original proposal but not due to material deviation of a structural nature.
- When sanctioned estimate is found to be more than actual requirements.

Supplementary estimate:

Sometimes some changes on additional works due to material deviation of a structural nature from the originally approved design may be thought necessary when the work is in progress.

For all such items, a separate detailed estimate is prepared, which is known as supplementary estimate.

- It is to be attached with a report describing the reasons for new additional work.
- The supplementary estimate is prepared for covering the estimate of sub-work of a project which is considered necessary to take full advantage of the development of the project after it is started.

(iii)

Escalation in the context of construction contracts:

- Escalation is a term used to indicate the extent of cost of labour and material changes from the commencement of a project through any point of time during progress or completion of project.
- So there is a provision in a contract for increasing or decreasing the contracted price for labour, material etc., in line with the market prices or as agreed upon benchmark such as consumer price index.
- The provisions of escalation are interrelated to protect the contractor from the fluctuating prices and to cater the labour wages with respect to inflation.

(iv)

EPF stands for employee provident fund and it is one of the main platform of saving for people working in government organisations or where government is the principal employer.

- Under this, both the employees and employer contribute equally to the employee provident fund at the fixed rate of the basic wages, salaries etc. per month.
- The EPF welfares the workers in following essential needs:

(i) Retirement
(ii) Medical care
(iii) Housing
(iv) Family obligation
(v) Education of children
(vi) Financing of insurance policies

Q.7 (c) Solution:

(i)

Contract : An agreement enforceable by law is called contract. The contract invariably follows a proposal from one party and its acceptance by the other.

Thus, contract is an agreement or an undertaking by a person or firm to do some work under certain terms and conditions. The work may be for the construction or maintenance and repairs, for the supply of materials, for the supply of labours, for transport of materials etc.

Essentials of Contract:

Following are the main essential requirements of a valid contract so that it may be legally binding on both the parties:

- Legally competent parties
- Free consent of the parties
- A lawful subject matter
- Proper and valid consideration
- Meaningful contract in writing signed by both the parties.

Legally competent parties:

As per Indian Contract Act, the parties entering into contract should be legally competent.

In general, any one can make the contract provided he is of the age of majority and is of sound mind. Signing officers should be in power to sign the contract i.e., no contracts shall be made by a subordinate authority who has not been directed or authorised to do so.

Free Consent of the Parties:

In other words, it is also called a genuine agreement or mutual consent between the two parties. It means concurring of two minds in respect of the same opinion, purpose or understanding as regards the course to be pursued. It is fundamental that there is no contract unless the parties do the same thing in the same sense viz offer and acceptance. The consent of contracting parties must be real and genuine. Contract is said to be free when:

- It is not caused under influence or coercion, the relation between two parties are not such that one of the parties is in a position to dominate the will of the others and uses the position to obtain an unfair advantage over the other.
- It is not caused by MISTAKE.

  Where the parties have not meant the using or though meaning the same thing, have formed untrue conclusions as to the subject matter, it is called MISTAKE. A mistake may be of expression, intention or omission.
- It is not caused by MISREPRESENTATION.

  If one of the parties has been led to form untrue conclusions as regards the subject matter by a statement innocently made or innocently withheld by the other, it is called MISREPRESENTATION
- It is not caused by FRAUD.

  Fraud is false representation of material facts intentionally.

- It is not caused under DURESS.

  To constitute duress there must be some actual or threatened exercise of power possessed by the party extracting or receiving the payments, over the person or property of the one assenting, from which the latter had no means of immediate relief other than by giving the assent sought.

  In case of mistake and misrepresentation, contract becomes invalid, both parties lose their claim but in case of fraud and duress, not only the contract becomes invalid, the party involved is subject to the legal punishment.

A lawful subject matter:

Contracts become invalid in the following cases;

(i) when the proposed contract violates some law of the state or Indian union.

(ii) when it is contrary to the rules of common law.

(iii) and when it is forbidden by the public policy.

It should also be noted that any person cannot escape from the responsibility by simply saying that he entered into the contract unknowingly, because it is his duty to study the subject matter of the contract carefully before signing any contract.

Proper and valid consideration:

The valid consideration in the legal sense can be defined as the act or a promise to do something by a party in return of money or promise or grant of some interests by the other party. In all engineering contracts, the contractors get money from the parties for whom the work is done. Impossible promises or acts are not entertained by the courts because there is no valid consideration.

The consideration may not be adequate or a full return of the promise, but it must be competent, real and should not be illegal, ambiguous, impossible or uncertain.

Meaningful contract in writing signed by both the parties:

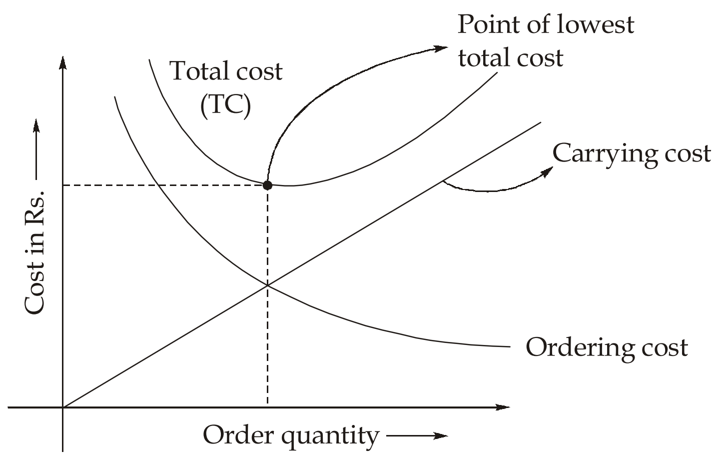
Meaning of the agreement should be certain or capable of being made certain and according to law the contract documents must be signed by the authorised persons of both the parties. In case of public bodies, an official duly authorised for this purpose signs the contract fixing the seal of the public body on the agreement.

(ii)

The economic order quantity or EOQ provides answer on how much to order. It is usually less expensive to purchase or produce a bench of material at once than to order it in small quantities.

If large order quantities are specified, then it means that quantity discounts and transportation efficiency may be realised but large lot size results in more inventory and inventory is expensive to hold.

Thus *EOQ* model attempts to specify a balance between these opposing costs, when it is clear that there is a decrease in cost associated with increase in order quantity, while there is increase in cost with increase of inventory.



EOQ is given by:

$$EOQ = \sqrt{\frac{2 \times A \times D}{I \times C}}$$

Where A = Ordering cost, Rs./order

D = Demand rate, unit/year

I = Inventory – carrying charges per year

C = Unit cost; Rs. unit of item.

Q.8 (a) Solution:

Calculation of depreciation using straight-line method

$$\text{Depreciation per year} = \frac{200000 - 50000}{5} = \text{Rs. } 30000/\text{year}$$

Year (m)	Opening book value	Annual depreciation	Closing book value
0	0	0	200,000
1	200,000	30,000	170,000
2	170,000	30,000	140,000
3	140,000	30,000	110,000
4	110,000	30,000	80,000
5	80,000	30,000	50,000

Calculation of depreciation using Sum of years digit method

Year (m)	Opening book value	Annual rate of depreciation	Annual depreciation	Closing book value
0	0	0	0	200,000
1	200,000	5/15	50,000	150,000
2	150,000	4/15	40,000	110,000
3	110,000	3/15	30,000	80,000
4	80,000	2/15	20,000	60,000
5	60,000	1/15	10,000	50,000

Calculation of depreciation using Double Declining Balance method

Year (m)	Opening book value	Annual rate of depreciation	Annual depreciation	Closing book value
0	0	0	0	200,000
1	200,000	0.4	80,000	120,000
2	120,000	0.4	48,000	72,000
3	72,000	0.4	22,000	50,000
4	50,000	0.4	0	50,000
5	50,000	0.4	0	50,000

Calculation of depreciation using sinking fund factor method

$$\because \quad D = (C_i - C_s)\left[\frac{i}{(1+i)^n - 1}\right] = (2{,}00{,}000 - 50{,}000)\left[\frac{0.08}{1.08^5 - 1}\right] = 25{,}568.47$$

Depreciation at end of M^{th} year $= D_m = D(1 + i)^{m-1}$

EOY	m	Depreciation (D_m)	Book Value
0			200,000.00
1	1	25,568.47	174,431.53
2	2	27,613.95	146,817.58
3	3	29823	116,994.58
4	4	32208.9	84785.68
5	5	34785.62	50,000.00

Q.8 (b) Solution:

(i)

Given: Capacity of shovel = 126 m^3/hr

Job management factor = 0.80

Operating efficiency = $\frac{45}{60}$ = 0.75

Depth-swing correction factor= 0.860

∴ Capacity of power shovel = 126 × 0.75 × 0.86 × 0.80 = 65.016 m^3/hr

∴ Total time required for completion of project = $\frac{296000}{65.016 \times 42 \times 46}$ = 2.356 yrs

If work is to be completed in 1000 hours then

Total capacity of shovel required = $\frac{296000}{1000}$ = 296 m^3

∴ No. of power shovels required = $\frac{296000}{65.016 \times 1000}$ = 4.553 ≃ 5 power shovels

(ii)

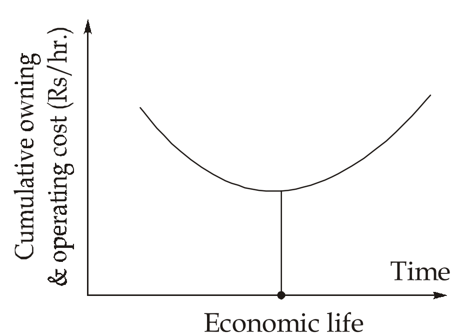
Factors affecting selection of a construction equipment:

- Availability of the equipment
- Economic life of the equipment
- Suitability of equipment for future
- Cost benefit analysis
- Safety considerations
- Operating cost of the equipment
- Size of the equipment
- Design of the equipment
- Size of project
- Need for any special equipment

Economic life of an equipment:

The economic life of any equipment can be defined as the age of replacement that maximises the profit returns from the equipment or minimizes the cumulative hourly owning and operating cost.

The economic life of an equipment is determined by plotting a graph between total cost (ownership cost + operating cost) per hour of an equipment with time. The point having minimum cost gives the economic life of the equipment.



Ownership and operating cost of the equipment includes

- Depreciation and replacement cost
- Return on investment (ROI)
- Maintenance and repair cost
- Downtime cost
- Obsolescence cost

Q.8 (c) Solution:

Methods of tunnelling in hard rocks:

In hard rocks generally following methods of tunneling are more common:

1. Full face method
2. Heading and benching method
3. Drift method
4. Pilot tunnel method

1. **Full face method.** This method is adopted for tunnels whose length is not more than 3 metres. Large size tunnels in rocks are always driven by this method. With the development of drill carriage, this method is becoming more and more popular. In this method vertical columns are fixed at the face of the tunnel to which a large number of drills may be mounted or fixed at any suitable height. A series of drill holes are drilled at about 120 cm centre to centre in any number of desired rows, preferably in two rows. The size of the holes may vary from 10 mm to 40 mm. These holes are then charged with explosives and ignited. The muck is removed before the next operation of drilling holes. This tunnel is more suitable for diameters less than 6 m and face area less than 19 m^2.

   Advantages of full face method:

   1. It requires minimum equipment. Hence it is simple in operation.
   2. The magnitude of ground disturbance and settlement is minimum in this method.
   3. The work is easily and speedily completed by this method.
   4. The mocking trucks can be laid once for all on the tunnel floor and extended progressively.
   5. It is found advantageous in sensitive ground conditions where multiple phase excavation could generate excessive ground pressure and settlement effects.

2. **Heading and bench method:** The top portion is known as the heading and the bottom portion as bench. Usually this method is adopted for railway tunnels. In this method of tunnelling the top portion of heading will be about 3.70 m to 9.6 m ahead of the bottom portion. In hard rock which may permit the roof to withstand without supports, the top heading usually is advanced by one round of the bottom portion. If the rock is broken then heading may be driven well ahead of the bottom portion and after giving proper support to the roof, the bottom portion is completed. In hard rock the heading is bored first and the drill holes are driven for the bench or bottom portion at the same time as the removal of the muck. This is the main advantage of this method. It requires less explosives than full face method.

   The advantages and disadvantage of this method are similar to the drift method.

3. **Drift method:** Drift is a small tunnel, usually its size is 300 cm × 300 cm. In driving a large tunnel it has been found advantageous to drive a drift first through the full length or in a portion of the length of the tunnel prior to excavating the full bore. The drift may be provided at the centre, sides, bottom or top as desired. In this method after driving the drift, the drill holes are drilled all round the drift in the entire cross-section of the tunnel, filled with explosives and ignited. The rock shatters, the muck removed and the tunnel expanded to the full cross-section.

   Advantages of drift method:

   (a) By this method any bad rock or excessive water will be discovered prior to driving full tunnel enabling to take corrective measures at the earliest.

   (b) The drift assists in ventilating the tunnel during later operations.

   (c) The quantity of explosive required is reduced.

   (d) The side drifts provide facility to install timbering to provide support to the roof, specially when the tunnel is driven in broken rock.

   Disadvantages of drift method:

   (a) Driving of main tunnel get delayed until the drift is finished.

   (b) As the drift is a small hole, the cost of drilling and handling muck will be high as the work has to be performed manually instead of power driven equipment.

4. **Pilot tunnel method:** In this method usually two tunnels are to be driven (1) main tunnel (2) pilot tunnel.

Actually this method is adopted to expedite the driving of the main tunnel. The cross-section of the pilot tunnel is usually 240 cm × 240 cm and driven parallel to the main tunnel. The pilot tunnel which is first driven to the full length is connected to the centre line of the main tunnel. The main tunnel then can be started from a number of points. The pilot tunnel also serves the following purposes:

1. It helps in removing muck from the main tunnel quickly.
2. It helps in providing proper ventilation in the main tunnel.
3. It helps in providing proper lighting in the main tunnel.

Advantages of pilot tunnel method:

1. The cross headings can be used for storing tools and materials during construction period.
2. It is found cheaper than central shaft method.
3. Chances of falling materials into the tunnel during construction are reduced considerably.
4. It avoids dislocation of strata at the sides of the tunnel.
5. After completion of work, cross headings may be used as passage by workers engaged in repair and maintenance.
6. The shafts may be lowered to act as sump for the collection of seeping water. Thus these shafts may be used as means of pumping water and artificial ventilation by the use of pumps and fans respectively.

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