SECTION—A

1. (a)

(i) Write the qualities of good timber and the factors affecting the strength of timber.

Answer.(i)

CHARACTERISTICS OF GOOD TIMBER

The principal characteristics of timber of concern are strength, durability and finished appearance.

1. Narrow annual rings, closer the rings greater is the strength.
2. Compact medullary rays.
3. Dark colour.
4. Uniform texture.
5. Sweet smell and a shining fresh cut surface.
6. When struck sonorous sound is produced.
7. Free from the defects in timber.
8. Heavy weight.
9. No woolliness at fresh cut surface.

The **strength of timber** depends on several factors related to its source, structure, and condition. Here's a detailed list:

1. Moisture Content

- Timber with high moisture (green timber) is weaker and more prone to decay.
- **Seasoned timber** (dried to optimum moisture level) is stronger and more durable.

2. Growth Conditions

- **Rate of growth**: Closer and narrower annual rings generally mean higher strength.
- Climate, soil quality, and availability of water during tree growth also affect strength.

3. Grain Structure

- **Straight-grained timber** is stronger than timber with cross-grain or twisted grain.
- Irregular grain can cause weak points and reduce load-carrying capacity.

4. Presence of Defects

- **Knots, cracks, shakes, splits, and insect damage** reduce the strength of timber.

5. Age of Tree at Harvesting

- Timber from a **mature tree** has better developed heartwood, which is denser and stronger compared to young sapwood.

6. Density

- **Heavier (denser) timber** generally has more strength than lighter wood of the same species.

7. Type of Timber (Species)

- Hardwoods (e.g., teak, oak) are usually stronger than softwoods (e.g., pine, cedar) due to higher density and stronger fiber structure.

8. Treatment and Preservation

- Chemical treatment to resist pests, fungi, and moisture can help retain strength over time.

9. Temperature and Exposure Conditions

- Extreme heat can cause timber to dry excessively and become brittle.
- Prolonged damp conditions can promote fungal decay, reducing strength.

(ii) Write short notes on any three of the following:

(1) Brick buttresses

(2) Brick corbel

(3) Brick coping

(4) Thresholds

(5) Brick jambs

(6) Racking back

Answer.

1) Brick Buttresses

- **Definition**: A brick buttress is a projecting masonry structure built to reinforce or support a wall against lateral forces such as wind pressure, earth thrust, or roof thrust.
- **Purpose**:
    - To improve stability of long walls.
    - To prevent bulging or leaning in tall or thin walls.
- **Construction**:
    - Built integral with the wall or bonded properly at regular intervals.
    - Can be stepped or sloped in profile for aesthetic and structural purposes.
- **Example Use**: Common in old churches, retaining walls, and compound walls.

2) Brick Corbel

- **Definition**: A corbel is a series of brick courses projecting out from the face of a wall in a stepped fashion.
- **Purpose**:
    - To support additional loads like beams, balconies, parapets, or arches without vertical supports.
    - Decorative architectural element.
- **Construction**:
    - Each successive course projects a small distance (usually 1/3 of brick thickness) beyond the one below.
    - Needs proper bonding to transfer loads safely into the wall.
- **Example Use**: Medieval building overhangs, supports for window shades.

3) Brick Coping

- **Definition**: Coping is the protective top layer or capping provided on the top of a wall.
- **Purpose**:
  - Protects wall from rain penetration and weathering.
  - Improves the appearance of the wall.
- **Types**:
  - Flat coping, sloped coping, saddle coping (slopes both ways).
  - May be made with special coping bricks, stone, or concrete.
- **Construction**:
  - Laid with a slope or drip groove to shed water away from the wall face.

4) Thresholds

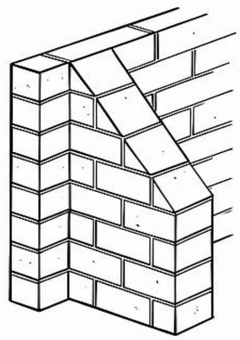
- **Definition**: A threshold is the horizontal member at the base of a doorway.
- **Purpose**:
  - Acts as a transition strip between two floor finishes or between indoors and outdoors.
  - Prevents dust, water, and insects from entering.
  - Takes the wear of pedestrian traffic.
- **Materials**:
  - Stone (marble, granite), timber, brick, or concrete.
- **Construction Note**:
  - Should be level or slightly sloped outward for drainage.

5) Brick Jambs

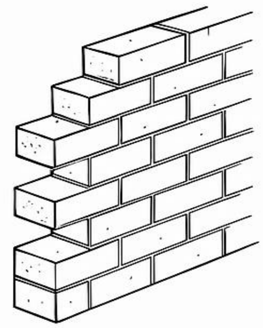
- **Definition**: Jambs are the vertical sides of a window or door opening in a wall.
- **Purpose**:
    - Provides a finished vertical face for openings.
    - Offers structural support for fixing door and window frames.
- **Construction**:
    - In brickwork, jambs are built using **closers** and proper bonding to maintain strength.
    - Can be **flush jambs** or **rebated jambs** depending on frame fixing requirements.

6) Racking Back

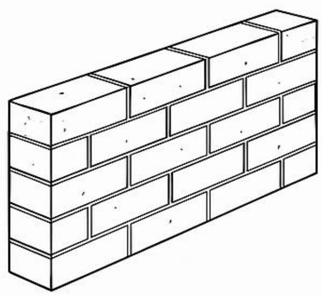
- **Definition**: Racking back is a method of terminating brickwork temporarily without leaving a straight vertical joint.
- **Purpose**:
    - Prevents weak vertical joints when work is resumed.
    - Maintains proper bond and strength of wall.
- **Construction**:
    - The unfinished end is left in a stepped manner with bricks progressively reduced in height.
    - When continued later, the new brickwork interlocks with the stepped end.



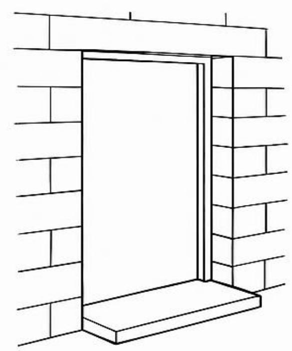
BRICK BUTTRESSS



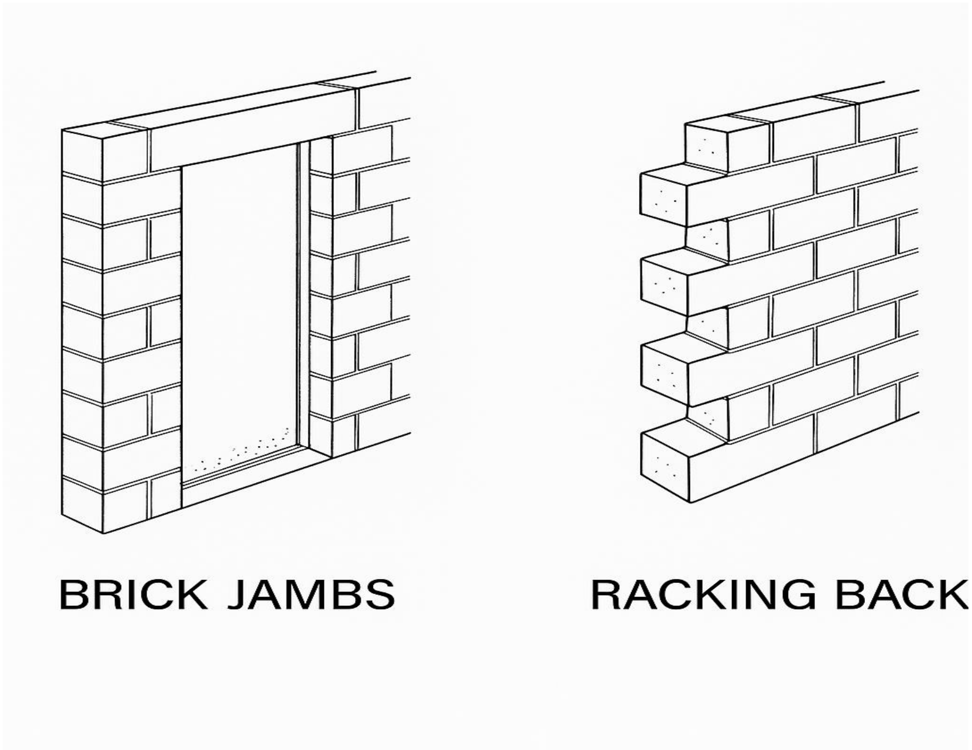
BRICK CORBEL



BRICK COPING



THRESHOLD



(e) A four-wheel tractor weighing 18000 kg has weight distribution between the front and the rear wheels of 40 percent and 60 percent respectively. It is operating on a level haul road whose rolling resistance is 45 kg/ton . What is the maximum rimpull of the tractor if the coefficient of traction between the road surface and the tyre is 0.65? 12

Answer.

Gross weight of tractor = 18,000 kg = 18 t

Hence rolling resistance offered by haul road (@ 45 kg/t) = 18 × 45 kg
= 810 kg

Load on driving tires = (60/100) × 18,000 = 10,800 kg

Maximum possible rimpull prior to slippage of tires = coefficient of traction × Load on driving tires
= 0.65 × 10,800 = 7020 kg

∴ Maximum effective rimpull = 7020 − 810 = 6210 kg. **Ans.**

2.(b) Explain the following terms:

(i) Autogenous shrinkage

(ii) Bogue compounds

(iii) Case-hardening

(iv) Elastomers

(v) Guniting

(vi) Scoriaceous aggregate

(vii) Self-desiccation

(viii) Shingling

(ix) Puddling

(x) Wet rot

2×10=20

Answer

(i) Autogenous shrinkage, also known as self-desiccation, is the reduction in volume of concrete due to the chemical reactions within the material during hydration, even without external factors like temperature change or moisture loss. This shrinkage is particularly noticeable in high-performance concrete with low water-to-binder ratios.

Factors Influencing Autogenous Shrinkage:

- **Water-to-Binder Ratio:** Lower water-to-binder ratios lead to increased autogenous shrinkage.
- **Cement Type:** Different cement types and supplementary cementitious materials (SCMs) can affect the rate and magnitude of shrinkage.
- **Temperature:** Temperature changes can influence the rate of hydration and subsequently affect autogenous shrinkage.

(ii) There are four compounds (Called Bogue's Compounds) formed as a result of hydration of cement:

- **Alite**: C_3S, or Tricalcium Silicate
- **Belite**: C_2S, or Dicalcium Silicate
- **Aluminate phase**: C_3A, or Tricalcium Aluminate

- **Ferrite phase**: C_4AF, or Tetracalcium Aluminoferrite

Bogue Compounds

a) Dicalcium Silicate (C_2S)

- Also called **Belite**.
- Undergoes a slow reaction.
- Responsible for progressive strength of concrete.
- Higher percentage results in slow hardening, less heat of hydration, and **great resistance to chemical attack**.

b) Tricalcium Silicate (C_3S)

- Also called **Alite**.
- Hydrates within one week.
- Helps in early-stage strength development (hardening).
- Best cementitious property among all Bogue's compounds.
- **Hardens rapidly** and is largely responsible for initial set and early strength.
- Higher C_3S content is good for cold weather concreting.

c) Tricalcium Aluminate (C_3A)

- Also called **Celite**.
- Quickest to react with water; responsible for flash setting.
- Increased content used for quick setting cement.
- Provides **weak resistance** to sulphate attack.
- Contribution to strength is significantly less than C_2S and C_3S.

d) Tetracalcium Aluminoferrite (C_4AF)

- Also called **Felite**.
- Poorest cementing value.
- Responsible for long-term strength gain of cement.

(iii) Case hardening is a heat treatment process that creates a hard, wear-resistant surface layer (the "case") on a metal part while maintaining a softer, more ductile core. This combines the benefits of both hard and soft metals – the hard surface resists wear and abrasion, while the core provides toughness and impact resistance. It's often used for components like gears, shafts, and other parts that experience wear and stress.

(iv) Elastomers are a type of polymer known for their high elasticity, meaning they can be stretched significantly and return to their original shape. This elasticity arises from the coiled structure of their polymer chains, which straighten out when stretched and recoil when the stress is removed. They are often referred to as rubber-like materials due to their flexibility and ability to deform under force

(v) Guniting, also known as dry-mix shotcrete, is a construction technique where a mixture of cement, sand, and water (or a dry mix that is hydrated at the nozzle) is sprayed onto a surface using compressed air. This process is used for repairing damaged concrete, creating new concrete surfaces, and strengthening structures, among other applications.

(vi) Scoriaceous aggregate refers to a lightweight aggregate material derived from scoria, a type of volcanic rock characterized by its porous, vesicular (bubble-filled) structure. This material is commonly used in construction, particularly in lightweight concrete, due to its low density and other beneficial properties.

(vii) Self-desiccation in concrete is a phenomenon where the hydration of cement consumes internal water, leading to a reduction in relative humidity and potential micro-cracking, especially in concretes with low water-to-cement ratios. This process occurs because the chemical reaction between cement and water produces hydration products that occupy less volume than the original components, creating a void and causing internal drying.

(viii) In construction, "shingles" most commonly refers to roofing shingles, which are overlapping pieces of material used to create a waterproof and weather-resistant roof covering. These individual elements are layered to shed water and protect the building from the elements. They are a popular choice for both residential and commercial buildings due to their durability, functionality, and aesthetic appeal.

(ix) Concrete puddling, in the context of concrete work, refers to the process of compacting wet concrete, typically using tools like a puddler or a vibrator, to eliminate air pockets and ensure a dense, uniform mass. This process is crucial for achieving proper consolidation and a smooth, level surface in various concrete applications like floors, foundations, and pavements.

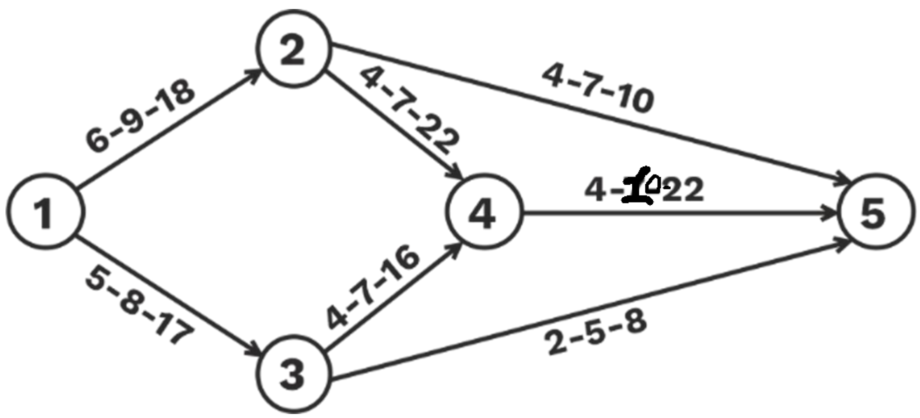
(x) Wet rot is a type of wood decay caused by fungi that thrive in damp conditions. It's characterized by the softening and weakening of timber due to fungal activity, specifically when the wood's moisture content is high (typically above 20-50%). Unlike dry rot, wet rot remains localized to the area with the moisture source and doesn't spread through masonry

3. (a) For the network shown below, the time estimates (in days) for each activity are mentioned. Determine the probability of completing the project in 35 days.

Given:

Standard normal distribution function

Z	P% (% probability)
0.8	78.51
0.9	81.59
1.0	84.13
1.1	86.43
1.2	88.49



Answer

ACTIVITY	to	tm	tp	te=(to+4tm+tp)/6	EVENTS	T_E	T_L	SLACK	σ^2
1-2	6	9	18	10	1	0	0	0	4
1-3	5	8	17	9	2	10	10	0	4
2-4	4	7	22	9	3	9	11	2	9
3-4	4	7	16	8	4	19	19	0	4
2-5	4	7	10	7	5	30	30	0	1

3-5	2	5	8	5	-			1
4-5	4	10	22	11	-			9

Critical path is 1-2-4-5

Standard deviation along critical path σ= √4+9+9= 4.69

Ts =35 days , T_E = 30 days , Z= (Ts- T_E) / σ = 1.066

From table probability @ Z= 1.492 , = 85.6%

(b) The initial cost of an equipment is ₹1,100, salvage value is ₹100, life of the equipment is 5 years. The rate of interest for sinking fund is 8%. Calculate the yearly depreciation and book value at the end of each year by straight line method, declining balance method, sum of years digital method and sinking fund method. Present the value in tabular form. 20

Answer

- Initial Cost (C): ₹1,100
- Salvage Value (S): ₹100
- Useful Life (n): 5 years
- Sinking Fund Interest Rate (r): 8%

1. Straight-line method

The straight-line method spreads the depreciation evenly over the asset's useful life.

- Annual Depreciation (D) = (C - S) / n
    - = (₹1,100 - ₹100) / 5
    - = ₹1,000 / 5
    - = ₹200 per year
- Book Value (BV) at the end of 'm' years = C - (m × D)

Year	Annual Depreciation (₹)	Accumulated Depreciation (₹)	Book Value (₹)
0	-	-	1,100
1	200	200	900
2	200	400	700
3	200	600	500
4	200	800	300
5	200	1,000	100

2. Declining balance method (assuming a depreciation rate)

This method applies a fixed depreciation rate to the declining book value each year.

- Depreciation Rate = (1 - (Salvage Value / Cost)^(1 / Useful Life))
  - = 1 - ((₹100 / ₹1100)^(1/5))
  - = 1 - (0.0909)^(0.2)
  - = 1 - 0.6186
  - = 0.3814 or approximately 38%
- Depreciation Expense = Beginning Book Value × Declining Balance Rate

Year	Beginning Book Value (₹)	Depreciation Expense (₹)	Accumulated Depreciation (₹)	Ending Book Value (₹)
0	1,100	-	-	1,100
1	1,100	1,100 × 0.3814 = 419.54	419.54	680.46
2	680.46	680.46 × 0.3814 = 259.57	679.11	420.89
3	420.89	420.89 × 0.3814 = 160.67	839.78	260.22
4	260.22	260.22 × 0.3814 = 99.30	939.08	160.92
5	160.92	60.92 (To reach salvage value)	1,000	100

3. Sum of the years' digits (SYD) method

This accelerated method depreciates more in the early years by applying a fraction to the depreciable amount.

- Sum of Years' Digits (SYD) = n × (n + 1) / 2
    - = 5 × (5 + 1) / 2

    - = 5 × 6 / 2
    - = 15
- Depreciation Factor = (n-m+1)/SYD
- Depreciable Amount = C - S
    - = ₹1,100 - ₹100
    - = ₹1,000
- Depreciation Expense = (Remaining Useful Life / SYD) × Depreciable Amount

Year	Remaining Useful Life	Depreciation Factor	Depreciation Expense (₹)	Accumulated Depreciation (₹)	Book Value (₹)
0	-	-	-	-	1,100
1	5	5/15	(5/15) × 1,000 = 333.33	333.33	766.67
2	4	4/15	(4/15) × 1,000 = 266.67	600	500
3	3	3/15	(3/15) × 1,000 = 200	800	300
4	2	2/15	(2/15) × 1,000 = 133.33	933.33	166.67

5	1	1/15	(1/15) × 1,000 = 66.67	1,000	100

4. Sinking fund method

This method sets aside a fixed amount annually and accrues interest to reach the target amount (Initial Cost - Salvage Value) at the end of the asset's life.

- Annual Sinking Fund Deposit (A) = (C - S) × (r / ((1 + r)^n - 1))
  - = (₹1,100 - ₹100) × (0.08 / ((1 + 0.08)^5 - 1))
  - = ₹1,000 × (0.08 / (1.469328 - 1))
  - = ₹1,000 × (0.08 / 0.469328)
  - = ₹1,000 × 0.170456
  - = ₹170.46
- Depreciation Expense for Year 'm' = A + (Interest earned on accumulated fund at the beginning of Year 'm')
- Accumulated Fund at the end of Year 'm' = (Accumulated Fund at the beginning of Year 'm' + A) × (1 + r)
- Book Value = C - Accumulated Fund

Year	Annual Deposit (₹)	Interest Earned (₹)	Total Depreciation Expense (₹)	Accumulated Fund (₹)	Book Value (₹)
0	-	-	-	-	1,100
1	170.46	0	170.46	170.46	929.54

2	170.46	170.46 × 0.08 = 13.64	170.46 + 13.64 = 184.10	(170.46 + 170.46) + 13.64 = 354.56	745.44
3	170.46	354.56 × 0.08 = 28.36	170.46 + 28.36 = 198.82	(354.56 + 170.46) + 28.36 = 553.38	546.62
4	170.46	553.38 × 0.08 = 44.27	170.46 + 44.27 = 214.73	(553.38 + 170.46) + 44.27 = 768.11	331.89
5	170.46	768.11 × 0.08 = 61.45	170.46 + 61.45 = 231.91	(768.11 + 170.46) + 61.45 = 1,000	100

SECTION-B

5. (a)

(i) What is smart concrete? Write the key features and benefits of smart concrete. 6

Answer.

A typical example of application of smart materials is of smart concrete developed by Dr. Deborah D.L Chung from state university of new york at Buffalo. It is a concrete reinfrorced by carbon fibres as much as 0.2% to 0.5% of volume to increase its sense ability to strain while still retaining good mechanical properties. By adding small amount of short carbon fibres into concrete, the electrical resistance of concrete increases in response to strain or stress. As the concrete is deformed or stressed, the contact between fibre and cement matrix is affected, there by affecting the volume electrical resistively of concrete. Strain is detected through measurement of the electrical resistance. So, the smart concrete has the ability to sense tiny structural flaws before they become significant, which could be used in monitoring the internal condition of structures. In addition, the presence of carbon fibres also control the cracking of concrete so that the cracks do not propagate catastrophically, as in the case of conventional concrete. By adding carbon fibers, the extra cost of material will increase by about 30%. This expense is still significant cheaper than attaching embedding sensors into structures. Smart concrete is stronger than conventional concrete because of carbon fibers. It takes greater force for smart concrete to bend, and it absorbs more energy before fracture. Monitoring can be a real time and continuous effort. Another possible use of Smart concrete is for the purpose of weighting vehicle on the highways. The highway made by this concrete could be able to determine where each vehicle was, and what its weight and speed were. Vehicles could be weighed while traveling normally on the highways. Smart concrete can also be used for real time vibrations sensing of bridges or other highway structures. It could also be used in buildings to dampen vibrations or reduce earthquake damage.

(ii) What is self-compacting concrete? How is it obtained? Explain the advantage and disadvantage of it. 6

Answer.

Self-Compacting concrete (SSC) first introduced in Japan is a very special type of concrete which can flow and fill into every corner of formwork, even in the presence of congested reinforcement, purely by means of its own weight and without the need of vibrating compaction, tamping etc. Self-Compacting concrete as it sounds is nothing different from normal concrete. It is just usage of extra admixtures (super plasticizers and viscosity modifying admixtures) and different amounts of composite materials that makes SSC act different to normal one. In SSC, high amount of supplementary cementitious materials, up to 70% of the total powder content, are added. Normally these supplementary materials are fly ash, silica flume, blast furnace slag etc. Since SSC does not require any compaction, it saves time, labour and energy. Also, good surface finish is produced.

Characteristics

Non-Segregating: The aggregate stay in suspension in the mix as it flows into the form.

Non-Bleeding: Water does not rise to the top of the mix or is observed on the outer edges of a flow test.

Vibration: No vibration is required during placement. SCC flows around rebar and other inclusions in the form under its own weight.

Flow spread: Flow spreads of 45 cm diameter or grater are obtainable.

Set time: The initial set time in many SCC mixes increase upwards of 90 minutes, depending on the admixtures used and water content of the mix.

Workability: Workability of Self-Compacting concrete is equilibrium of its fluidity, deformability and resistance to segregation and filling ability. This equilibrium has to be maintained for a sufficient time period to allow for its transportation, placing and finishing. For specific uses, for example Ready Mixed Concrete this time could be 90 minutes or more, if required, while for the precast concrete production, 30 minutes could be sufficient.

Limitations

Self-Compacting concrete has been used as a “special concrete” only by large construction companies. In order for Self-Compacting concrete to be used as a standard concrete rather than a special one, new systems for its design, manufacturing and construction need to be established and standardized.

(c) Explain the following terms, with sketches, pertaining to the masonry walls:

(i) Solid wall with piers

(ii) Cavity wall

(iii) Faced wall

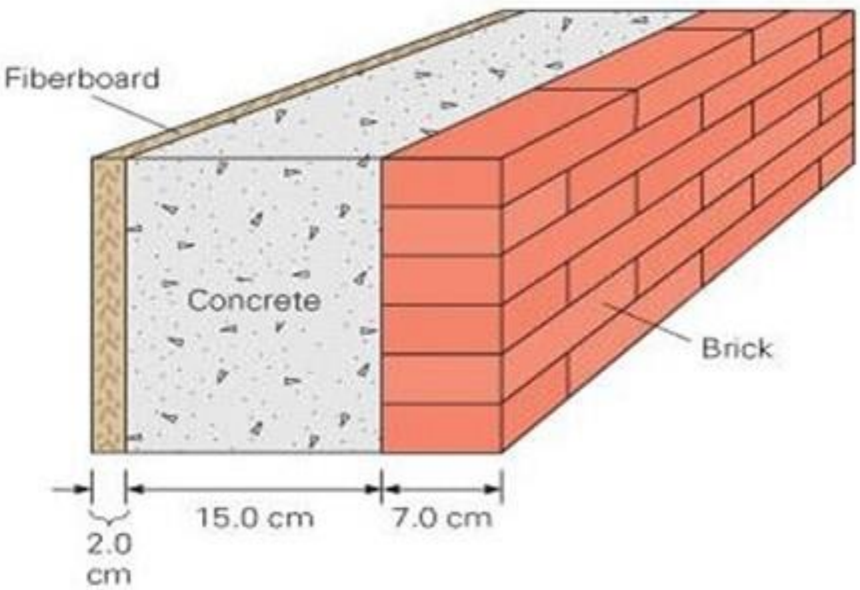
(iv) Veneered wall 12

Answer.

(i) Solid wall with piers: A solid wall with piers is a masonry wall constructed with a continuous section of masonry, reinforced by additional vertical piers at regular intervals. These piers provide extra structural support to the wall, allowing it to withstand heavier loads or span longer distances.

(ii) Cavity wall: A cavity wall consists of two separate masonry wythes (layers) built with an air gap between them. This cavity creates insulation, improves ventilation, and can help drain water from the wall, preventing moisture issues. The outer wythe is typically faced with brick or stone for aesthetics, while the inner wythe can be made of concrete blocks or other materials.

(iii) Faced wall: A faced wall is a masonry wall where only the exterior surface is made of aesthetically pleasing materials like brick or stone. The interior of the wall can be constructed with less expensive materials like concrete blocks or concrete fill. This type of wall provides a visually appealing facade while maintaining a cost-effective construction.



(iv) Veneered wall: A veneered wall is similar to a faced wall, but the exterior layer (veneer) is not structurally load-bearing. It is typically thin and attached to a supporting structural wall behind it. Veneered walls are often used for aesthetic purposes, adding a finishing touch to a building's exterior.

7. (a)

(i) What is ferrocement and fiber-reinforced concrete? Write their advantages and disadvantages. 8

Answer.

FERROCEMENT

Ferrocement is a composite material in which the filler material (called matrix), cement mortar, is reinforced with fibres, usually steel mesh dispersed throughout the composite, which results in better structural performances than individual ones. The fibres impart tensile strength to the mass.

In rationally designed ferrocement structures the reinforcements consist of small diameter wire meshes wherein uniform distribution of reinforcement is made possible throughout the thickness of the element. Because of the distribution of such reinforcement over the entire matrix, high resistance to cracking is achieved. Toughness, fatigue resistance, impermeability, etc. are also improved. This material which is a special form of reinforced concrete, exhibits a behavior so different from conventional reinforced concrete in performance, strength and potential application that it must be classed as a separate material.

Ferrocement is used in thin-walled structures where strength and rigidity are developed through form or shape. It has the distinct advantage of being moldable and of one-piece construction. Other major advantages are its low cost and its non-flammability and high corrosion-resistance characteristics. The advantages of ferrocement are:

1. Easy availability of raw materials.
2. Reduction in weight consequent of thin section.
3. Moulding can be done without any formwork.
4. No machinery or sophistication is required in construction.

Main **drawbacks of ferrocement** (with why they matter in practice):

- **High corrosion risk**
  Very large steel surface area and thin cover make the meshes vulnerable to chloride/moisture ingress. Local rusting can spread fast through the fine wires.
- **Shrinkage & early cracking tendency**
  Rich mortar (high paste) plus many steel–mortar interfaces increase drying-shrinkage and thermal-shrinkage stresses if curing is not excellent.
- **Workmanship-sensitive / quality control is hard**
  Full mortar penetration through multiple mesh layers is difficult; voids or honeycombing severely reduce durability and strength. Careful mixing, plastering/shotcreting, and curing are essential.
- **Labor-intensive fabrication**
  Cutting, shaping and tying several fine meshes takes time and skilled hands; productivity is lower than conventional RC unless prefab panels are used.

FIBRE REINFORCED CONCRETE

Conventional concrete is modified by random dispersal of short discrete fine fibres of asbestos, steel, glass, carbon, poly-propylene, nylon, etc. Asbestos cement fibres so far have proved to be commercially successful. The improvement in structural performance depends on the length characteristics, volume, spacing, dispersion and orientation, shape and their aspect ratio (ratio of length to diameter) of fibres. A fibre reinforced concrete requires a considerably higher cement paste of given quality than that for conventional concrete for compaction and handling. For FRC to be fully effective, each fibre needs to be fully embedded in the matrix, thus the cement paste requirement is more. For FRC the cement paste required ranges between 35 to 45 per cent as against 25 to 35 per cent in conventional concrete.

The tensile cracking strain of cement matrix is about 1/50 of that of steel in direct stress. Consequently when FRC is loaded, the matrix cracks long before the fibres are fractured. Once the matrix is cracked the fibres continue to carry the load at increasing stress, provided the pull-out resistance of fibres at first crack is greater than the load at the onset of cracking. The strength of bonding between the fibres depends on the average bond strength between the matrix and the fibres, the number of fibres across the crack and the aspect ratio, length and diameter of fibres, and the aspect ratio.
The first fibre crossing the crack on a FRC member increases the load to peak after stretching of the first fibre, the crack starts increasing causing stress redistribution among the closely spaced fibres. After reaching peak load there is a residual load provided the bond is good. Therefore the fibres, when bonded effectively, increase the tensile area of the section and the fibres in adjacent layers fracture in sequence at the breaking strain. Failure occurs when the concrete in compression reaches the ultimate strain.

Advantages

1. Strength of concrete increases.
2. Fibres help to reduce cracking and permit the use of thin concrete sections.
3. Mix becomes cohesive and possibilities of segregation are reduced.
4. Ductility, impact resistance, tensile and bending strength are improved.

Disadvantages

1. Fibres reduce the workability of a mix and may cause the entrainment of air.
2. Steel fibres may corrode and can stain the concrete surface.
3. Finishing becomes difficult because fibres may protrude at the surface.
4. Cost increases due to fibres and higher paste content.

Applications

Fibre reinforced concrete has been used in hydraulic structures, airfield pavements, highways, bridge decks, harbour works, and tunnel linings.

(ii) Describe, in short, the various methods of proportioning concrete. 6

Answer.

Various Methods of Proportioning Concrete are as follows

(a) Arbitrary proportion
(b) Fineness modulus method
(c) Maximum density method
(d) Surface area method
(e) Indian Road Congress, IRC 44 method
(f) High strength concrete mix design
(g) Mix design based on flexural strength
(h) Road note No. 4 (Grading Curve method)
(i) ACI Committee 211 method
(j) DOE method
(k) Mix design for pumpable concrete
(l) Indian standard Recommended method IS 10262-82

- **Arbitrary proportion:** Nominal volumetric mixes (e.g., 1:2:4); quick, not strength-controlled.

- **Fineness modulus method:** Chooses fine/coarse aggregate ratio from FM to get workable grading.

- **Maximum density method:** Proportions aggregates to minimize voids (Fuller curve) → less paste needed.

- **Surface area method:** Fixes paste content from total aggregate surface area required for coating/workability.

- **IRC-44 method:** Indian Roads Congress procedure for **pavement concrete** using target **flexural strength**, w/c limits, and pavement-specific grading.

- **High-strength concrete design:** Very low w/b, higher cementitious + admixtures; performance/strength driven.

- **Flexural-strength based mix:** Designs for a target **modulus of rupture** (common for slabs/roads).

- **Road Note No. 4 (grading-curve):** UK RRL curves to blend aggregates for dense, well-graded concrete.

- **ACI 211:** Table/plot-based US method—select w/c for target f′c, estimate water, air, and aggregate contents, then trial mixes.

- **DOE method:** British method—compute target mean strength (fck + margin), pick w/c and water, adjust by workability/size.

- **Pumpable-concrete mix:** Ensures continuous grading and adequate fines/mortar for pumping without segregation.

- **IS 10262 (India):** Standard Indian mix-design—target mean strength, exposure-based w/c, water demand, and adjustments via trials.

(iii) Write, in short, the various advantages of RC structures over other masonry structures. 6

Answer.

Key advantages of RC over masonry

- **Higher load capacity & longer spans**
  Concrete takes compression while steel bars take tension, so RC beams/slabs/columns can carry far greater loads and bridge longer spans (flat slabs, girders, waffle slabs) than masonry walls, which mainly work in compression and need frequent supports.
- **Ductility & seismic performance**
  Steel reinforcement gives RC members ductility and energy dissipation under earthquakes. With proper detailing (anchors, confinement, ties, shear walls), RC frames avoid brittle failure typical of unreinforced masonry and can be designed for controlled plastic hinges and redistribution.
- **Monolithic action & continuity**
  Cast-in-situ RC is poured as continuous members (slab–beam–column–foundation), giving integral behavior, better load sharing, and redundancy. Masonry is jointed (many mortar interfaces) and acts as discrete walls, making continuity and redistribution limited.
- **Resistance to lateral loads (wind/quake)**
  RC frames, cores, and shear walls efficiently resist racking and overturning. Load-bearing masonry is comparatively poor in tension and shear, and wall thickness must grow rapidly with height.
- **Architectural flexibility & usable space**
  RC frames free the floor plan from load-bearing interior walls, allowing **large openings**, **cantilevers**, atriums, parking basements, and **thin slabs**—which also increase carpet area compared with thick masonry walls.
- **Speed & constructability (incl. precast)**
  RC work can be mechanized (pumping, slip-/jump-forms) and standardized. Precast RC components enable fast erection and factory quality—options rarely available for masonry beyond small blocks.
- **Service integration & future alterations**
  Conduits, sleeves, and embeds can be cast into RC; non-structural partitions can be moved later. In load-bearing masonry, many walls are structural, so altering openings or reconfiguring plans is harder and riskier.

- **Water-retaining & soil-retaining structures**
  Monolithic RC is suitable for tanks, basements, swimming pools, retaining walls, shells, and bridges. Masonry's many joints make watertightness and soil pressure resistance difficult.

- **Fire performance**
  RC is non-combustible, and cover concrete insulates reinforcing steel, providing good fire resistance for structural members. Masonry is also non-combustible, but RC permits slender fire-rated beams/columns that masonry cannot provide.

- **Durability & environmental exposure**
  With correct cover, low w/c ratio, and pozzolans, RC resists weathering, decay, and pests; it performs well in marine/industrial atmospheres when designed for durability. Masonry mortars and joints are more vulnerable to moisture ingress and freeze–thaw (where applicable).

- **Quality control & codified design**
  RC has well-developed mix designs, tests (slump, cube/cylinder strength), and detailing rules, enabling predictable performance and compliance. Masonry quality depends heavily on unit consistency and workmanship.

- **Robustness & progressive-collapse resistance**
  RC frames can be detailed with ties and continuity to maintain alternate load paths after local damage; unreinforced masonry is brittle and lacks such redundancy.

- **Acoustic/thermal mass**
  RC slabs/walls provide high mass, improving sound insulation and thermal stability (useful for roofs/floors), whereas achieving similar performance in masonry often needs thicker sections.

- **Economy at scale**
  For **multi-storey**, **long-span**, or **heavily loaded** buildings, RC is usually more economical per usable floor area than thick load-bearing masonry, and it reduces foundation loads by replacing many heavy walls with slender columns.

(c)

(i) Describe the different types of contract in brief. How is a tender document prepared? 10

Answer.

Contract type	How payment is computed	Risk mainly on	Where it fits / notes
Lump-sum / Fixed-price	One fixed price for the whole scope (drawings + specs). Variations paid only via change orders.	**Contractor** (time/cost overrun on his account, except approved changes)	Well-defined scope, minimal design change, buildings with good drawings.
Item-rate / Unit-price (remeasurement/measure-and-pay)	Bidder quotes rate for each BoQ item; final payment = **actual measured quantity × rate**.	**Owner** (quantity risk), contractor (productivity).	Linear works (roads, pipelines), earthwork, when quantities uncertain.
Percentage-rate	Bidder quotes % above/below a published Schedule of Rates; payment by SOR × (1±%); actual quantities measured.	Shared (quantity risk on owner).	Govt. works with standard SOR.
Time & Materials (T&M)	Agreed labour hourly rates + actual materials + markup.	**Owner** (productivity & total cost).	Emergency works, small unpredictable jobs; tight supervision needed.
Cost-plus % fee	Reimbursable cost + % fee.	**Owner**	Rare today—weak cost control/incentive.
Cost-plus fixed fee	Cost + fixed fee (₹).	Shared	Better cost control than % fee.

Contract type	How payment is computed	Risk mainly on	Where it fits / notes
Target cost with pain/gain share (Cost-plus incentive)	Target cost set; underruns/overruns shared as per formula.	**Shared** (strong collaboration).	Complex projects; encourages savings.
Guaranteed Maximum Price (GMP)	Reimbursable cost up to a cap; savings often shared.	**Contractor** beyond the cap.	Early contractor involvement; price certainty with flexibility.
Labour-only / Piece-work	Pay for labour or per piece; materials by owner.	Split	Repairs, finishing trades.
Framework/Rate contract / Term contract	Fixed rates for a basket of items over a period; work called off as needed.	Shared	O&M, repetitive small jobs.

Tender document is prepared in following steps.

1) Pre-tender groundwork

1. **Define need & scope**: purpose, deliverables, performance requirements.
2. **Choose delivery & contract type**: DBB vs Design-Build/EPC; Lump-sum vs Item-rate, etc.
3. **Investigations**: surveys, geotech, utilities, site constraints, permits.
4. **Cost estimate & budget**: owner's engineer estimate; funding & approvals.
5. **Procurement plan**: single stage or two-stage; one- or two-envelope; prequalification?

2) Draft the tender (bid) documents – typical contents

- **Volume 1 – Invitation & Instructions**
  - **Notice Inviting Tender (NIT)**: project title, eligibility, EMD/bid security, key dates, bid validity, how to obtain documents, submission method.
  - **Instructions to Bidders (ITB)**: how to prepare/submit bids; two-envelope rules; language, units; bid validity; pre-bid meeting; site visit; clarifications; addenda; opening & evaluation procedure; responsiveness criteria.
  - **Qualification/Eligibility**: experience, turnover, equipment, key personnel, past performance, litigation history; forms and checklists.
  - **Bid Forms**: letter of bid, power of attorney, JV details, deviations list, integrity/anti-collusion undertakings.
- **Volume 2 – Employer's Requirements / Technical**
  - **Scope of work** and performance specs; **drawings**; standards/codes; **quality requirements** (QAP/ITP), **HSE** plan; workmanship; testing/inspection; **work program** & **milestones**; access & interfaces; O&M (if any).
  - **Bill of Quantities (BoQ)/Schedule of Items**: item descriptions, units, estimated quantities (or rate-only items).
- **Volume 3 – Conditions of Contract**
  - **General Conditions (GCC)** (e.g., FIDIC/CPWD/State PWD base) and **Special/Particular Conditions (SCC/PC)** amending GCC.
  - **Contract Data**: start date, time for completion, liquidated damages/bonus, **price adjustment/escalation** formula, securities (**EMD/bid security**, **performance security**, **advance payment** & guarantee), **retention/mobilisation**, insurances, taxes/GST, change order/variation procedure, **dispute resolution** (DRB/arbitration), force majeure, termination, defects liability period.
  - **Payment terms & measurement**: interim payment schedule, measurement rules (BoQ, remeasurement, lump-sum with schedules), materials on site, price adjustment indices.
- **Volume 4 – Price/Bill (Financial Envelope)**
  - Price schedule/BoQ to be filled; breakdowns (e.g., resource rates), provisional sums, daywork schedules.

Two-envelope system: Technical bid opened first and evaluated for responsiveness & qualification; **Financial** bids of only qualified bidders are opened later.

3) Reviews & issue

1. **Technical/legal vetting**: cross-check scope, drawings, BoQ–spec alignment, risk allocation, caps/LDs.
2. **Approval of competent authority** and **publish NIT** (portal/newspaper).
3. **Pre-bid meeting** & minutes; issue **addenda** for clarifications.
4. Facilitate **site visits** and RFI responses.

4) Bid receipt, opening & evaluation (high level)

1. **Receive & time-stamp** bids; open **technical** bids; check **responsiveness** (EMD, signatures, forms).
2. **Evaluate qualification & technical** compliance; request clarifications (no change in price/essential terms).
3. Open **financial** bids of qualified bidders; **arithmetical check**, evaluate taxes, rebates, loading for deviations if allowed; rank (L1).
4. **Reasonableness check** vs engineer's estimate; investigate **abnormally low/high** bids; obtain approvals.
5. **Award**: issue **Letter of Acceptance (LoA)**; contractor submits **performance security** and signs the **agreement**; issue **Notice to Proceed**.

(ii) Estimate the number of carriers, if the data for the project are the following :

Quantity of material to be handled = 5000000 m^3

Capacity of the loaders to be engaged = 2.3 m^3

Capacity of bottom dampers = 30 m^3

Project to be completed in two shifts in 5 years with yearly working hours = 2000 hr

Job and management factor = 0.70

Operating efficiency = 0.85

Bucket fill factor = 0.85

Swell factor = 0.90

Cycle time for loader = 0.50 minute

Lead distance = 6 km

Speed during empty haul @ 25 km/hr and loaded haul @ 20 km/hr 10

Answer

1) Required Average Production

Available hours = 20,000 hr
Q_{req} = 5,000,000 / 20,000 = 250.00 m^3/hr

2) Loader Productivity & Count

Bucket (loose) = 2.3 × 0.85 = 1.955 m^3; in bank = 1.759 m^3
Effective cycles/hr = (60 / 0.5) × 0.70 × 0.85 = 71.40
Loader output = 1.7595×71.4= 125.63 m^3/hr
Loaders needed = 250/125.6 = 1.99 → adopt 2 loaders

3) Carrier Cycle & Output

Payload per truck (bank) = 27.00 m^3
Buckets per truck = 15.35; loading time = 7.67 min
Loaded travel = 18.00 min; Empty travel = 14.40 min; Dump/spot = 1.00 min
Truck cycle = 41.07 min; Effective trips/hr = 0.869
Per-truck output = 23.47 m^3/hr

4) Number of Carriers

$N_{carriers}$ = 250/23.5 = 10.65 → adopt 11 carriers