Chapter 14: Production of Concrete

Introduction

The production of concrete is a systematic and well-regulated process that ensures the final product meets desired strength, durability, and performance standards. It encompasses several stages: batching, mixing, transporting, placing, compacting, finishing, and curing. Each stage influences the quality of concrete significantly. Understanding these processes in depth is critical for civil engineers to produce concrete that is structurally sound and long-lasting.

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1. Batching of Concrete

Batching is the process of measuring the quantities of cement, aggregates, water, and admixtures to prepare the concrete mix.

1.1 Methods of Batching

- **Volume Batching:**
  - Ingredients are measured in terms of volume.
  - Commonly used for small construction sites.
  - Less accurate and may lead to inconsistencies in mix proportions.
  - Example: 1:2:4 mix (cement:sand:coarse aggregate) by volume.
- **Weigh Batching:**
  - Ingredients are measured by weight using a weigh batcher.
  - Most accurate and preferred method for modern construction.
  - Ensures consistency and reliability of mix proportions.
  - Required in quality control environments and ready-mix concrete (RMC) plants.

1.2 Tolerances in Batching

- Cement: ±1%
- Aggregates: ±2%
- Water: ±1%

- Admixtures: ±3%

Proper calibration of equipment and regular checks are essential for maintaining batching accuracy.

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2. Mixing of Concrete

Mixing ensures a uniform blend of the constituents to produce homogeneous and workable concrete.

2.1 Types of Mixing

- **Hand Mixing:**
    - Used in small works and emergencies.
    - Concrete is mixed manually on a platform.
    - Mixing quality depends on labor skill.
    - Usually limited to lower grade concrete (M10–M15).
- **Machine Mixing:**
    - More consistent and efficient.
    - Performed using concrete mixers (tilting or non-tilting type).
    - Common mixer types:
        - **Pan Mixer:** Used in precast concrete work.
        - **Drum Mixer:** Widely used for general construction.
    - Mixing time: Normally 1.5–2 minutes.
- **Ready Mix Concrete (RMC):**
    - Concrete mixed at a central plant and transported to the site.
    - Ensures high quality and consistency.
    - Reduces onsite labor and material wastage.
    - Requires careful monitoring of travel time and temperature.

2.2 Mixing Time and Uniformity

- Minimum mixing time must ensure uniform distribution of materials.
- Under-mixing causes weak spots, while over-mixing can lead to segregation and loss of workability.

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3. Transportation of Concrete

Once mixed, concrete must be transported quickly and efficiently to avoid setting before placement.

3.1 Factors Affecting Transportation

- Distance between mixing and placing point.
- Temperature and weather conditions.
- Slump/workability of concrete.
- Use of admixtures (e.g., retarders).

3.2 Methods of Transportation

- **Wheelbarrows and Head Pans:**
  - Common in small-scale construction.
  - Labor-intensive and suitable for short distances.
- **Buckets and Cranes:**
  - Used for vertical transportation on high-rise buildings.
- **Pumps:**
  - Most efficient method for modern construction.
  - Can deliver concrete to great heights and distances.
  - Requires pumpable mix design (suitable W/C ratio and grading).
- **Transit Mixers (RMC Trucks):**
  - Used for ready-mix concrete delivery.
  - Truck-mounted rotating drum prevents segregation and setting.
  - Must be delivered within 90 minutes of batching (as per IS 4926).

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4. Placing of Concrete

Placing refers to depositing concrete into the required position in the formwork.

4.1 Considerations During Placing

- Avoid segregation by placing concrete close to its final position.
- Do not pour concrete from excessive height (>1.5 m).

- Ensure layers are not allowed to set before the next layer is placed.
- Pour concrete continuously to avoid cold joints.

4.2 Techniques of Placing

- Manual placing using shovels or pans.
- Chutes and tremie pipes for inaccessible areas.
- Concrete buckets and cranes.
- Pumping, especially for high-rise or congested structures.

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5. Compaction of Concrete

Compaction eliminates air voids from freshly placed concrete, ensuring maximum density and strength.

5.1 Methods of Compaction

- **Hand Rodding and Tamping:**
  - Suitable for small-scale or unreinforced sections.
- **Vibration:**
  - Most effective method.
  - **Internal Vibrators (Needle Vibrators):** Inserted into the concrete mass.
  - **External Vibrators:** Attached to formwork; used for precast elements.
  - **Surface Vibrators:** Used for slabs and pavements.

5.2 Over-Vibration and Under-Vibration

- Over-vibration can lead to segregation.
- Under-vibration results in honeycombing and reduced strength.

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6. Finishing of Concrete Surfaces

Finishing enhances surface texture, aesthetics, and durability.

6.1 Finishing Techniques

- **Floating:** Using wooden or magnesium floats to level the surface.
- **Troweling:** Using steel trowels for smooth finish.
- **Brooming:** Provides skid resistance on pavements.

- **Stamping:** Decorative concrete surfaces using patterns and colors.

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7. Curing of Concrete

Curing is the process of maintaining adequate moisture, temperature, and time to allow proper hydration of cement.

7.1 Importance of Curing

- Enhances strength and durability.
- Reduces surface shrinkage and cracking.
- Promotes better bond development.

7.2 Curing Methods

- **Water Curing:**
  - Ponding, spraying, or wet coverings (e.g., hessian cloth).
- **Membrane Curing:**
  - Applying curing compounds to seal moisture.
  - Useful in dry and windy conditions.
- **Steam Curing:**
  - Used in precast plants for accelerated curing.
- **Self-Curing:**
  - Admixtures that retain moisture internally (e.g., SAP – superabsorbent polymers).

7.3 Duration of Curing

- Minimum 7 days for ordinary Portland cement.
- 10–14 days for blended cements (e.g., PPC, PSC).
- As per IS 456:2000, curing should be extended during cold weather.

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8. Quality Control in Concrete Production

To ensure the concrete produced meets design requirements, rigorous quality control is essential.

8.1 Quality Control Measures

- Testing of raw materials (cement, aggregates, water).
- Calibration of batching equipment.
- Slump test for workability.
- Compressive strength test (cube/cylinder).
- Non-destructive testing (NDT) for in-situ concrete.
- Proper documentation and record-keeping.

8.2 Field Tests on Concrete

Field tests are essential for assessing concrete quality in real-time. They help identify issues early during production or placement.

a) Slump Test

- Measures workability of fresh concrete.
- Conducted using a slump cone (300 mm high, 200 mm base, 100 mm top).
- Types of slumps:
  - True Slump – Good workability
  - Shear Slump – Inconsistent mix
  - Collapse Slump – Excessive water content

b) Compacting Factor Test

- Used for very low workability concrete (not suitable for slump test).
- Determines degree of compaction.
- Especially useful for concrete used in road construction or mass foundations.

c) Flow Table Test

- Used for testing highly workable or self-compacting concrete (SCC).
- Measures spread diameter after jolting on a flow table.

8.3 Laboratory Tests on Concrete

In addition to field tests, laboratory tests are conducted to verify hardened concrete properties.

a) Compressive Strength Test

- Cube specimens (150 mm) tested at 7 and 28 days.
- Carried out as per IS 516:1959.
- Most widely used parameter for structural design validation.

b) Split Tensile Strength Test

- Cylinder specimens placed horizontally in testing machine.
- Determines tensile strength of concrete.
- Helps in understanding cracking resistance.

c) Flexural Strength Test

- Also called Modulus of Rupture.
- Important for pavement and slab design.
- Based on beam testing (100 × 100 × 500 mm specimens).

8.4 Sampling and Acceptance Criteria

Sampling is done to ensure concrete quality throughout a batch or project.

a) Sampling Frequency

- For concrete volume up to 5 m^3: 1 sample.
- For 6–15 m^3: 2 samples.
- For 16–30 m^3: 3 samples, and so on.

b) Acceptance Criteria (as per IS 456:2000)

- Based on average strength of sample cubes.
- Minimum individual cube strength must not be less than 75% of characteristic strength.
- If results fall below limits, structure may require NDT or core testing.

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9. Automation in Concrete Production

Modern construction sites and RMC plants are increasingly adopting automation to improve quality, consistency, and efficiency.

9.1 Batching Plant Automation

- Fully automated plants control:
    - Ingredient proportioning (by weight)

- Moisture content correction
  - Real-time data logging
- Reduces human error and increases productivity.

9.2 Computer-Controlled Mixing

- Advanced software integrates:
  - Real-time feedback from sensors
  - Adjustments in water-cement ratio
  - Mixing time optimization

9.3 Sensors and IoT in Concrete Production

- Embedded sensors track:
  - Temperature
  - Hydration progress
  - Strength development
- Useful for critical infrastructure projects and precast elements.

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10. Environmental Considerations in Concrete Production

As sustainability becomes a core concern, concrete production methods are adapting to minimize environmental impact.

10.1 Carbon Footprint of Concrete

- Cement production is a major source of CO_2 emissions.
- Aggregate mining impacts land and water resources.
- Transport and energy usage add to environmental load.

10.2 Sustainable Practices

- Use of **supplementary cementitious materials (SCMs)**:
  - Fly ash, GGBS, silica fume
  - Reduces cement consumption and improves durability
- Recycled aggregates:
  - Derived from demolished concrete
  - Processed and graded for reuse

- Use of **low-carbon cements**:
  - LC3 (Limestone Calcined Clay Cement)
  - Blended cements

10.3 Waste Management

- Slurry water and washout from RMC plants must be treated.
- Reusing returned concrete as base layer material.
- Solid waste (e.g., leftover hardened concrete) can be crushed and used as RCA (Recycled Concrete Aggregate).

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11. Innovations in Concrete Production

Recent technological developments are revolutionizing how concrete is produced and applied.

11.1 Self-Compacting Concrete (SCC)

- Highly flowable and non-segregating.
- Eliminates need for vibration.
- Ideal for complex reinforcement zones or precast elements.

11.2 3D Printed Concrete

- Automated layering of concrete using robotic arms or gantries.
- Enables complex geometries and rapid construction.
- Challenges include material control and printing speed.

11.3 Ultra-High Performance Concrete (UHPC)

- Extremely high compressive (150–200 MPa) and tensile strength.
- Very low permeability.
- Used in bridges, security structures, and precast facades.

11.4 Green Concrete

- Made using industrial by-products and recycled materials.
- Lower carbon emissions, improved thermal efficiency.
- Can be customized for specific applications.
