Building Materials and Concrete Technology

Short notes for B.Tech Civil · GATE CE

Uncodemy Handwritten Notes · free for students

I. Stones

- Classification: geological (igneous, sedimentary, metamorphic), physical (stratified, unstratified, foliated), chemical (siliceous, argillaceous, calcareous).
- Good building stone: high crushing strength, low water absorption, durable, hard, tough, good appearance.
- **Dressing** = shaping stones; **quarrying** methods: hand tools, wedging, heating, blasting.

Test on stone	Property checked
Crushing test	Compressive strength
Water absorption	Porosity, durability
Attrition test	Resistance to wear (rubbing)
Impact test	Toughness
Acid test	Weather resistance (calcareous content)
Smith's test	Presence of soluble earthy matter

- Uses: granite (heavy works, flooring), basalt (road metal), sandstone (walls), marble (decorative), slate (roofing), laterite (local masonry).

2. Bricks

➤ Composition of good brick earth

Constituent	Approx. %	Role
Silica	50 to 60	Keeps shape; excess makes brick brittle
Alumina	20 to 30	Gives plasticity; excess causes cracks on drying
Lime	small (under 5)	Lowers fusion; excess melts brick
Iron oxide	about 5 to 6	Red colour, strength
Magnesia	under 1	Yellow tint

- Harmful: excess lime, lumps of lime (blow), alkalis (efflorescence), pebbles, iron pyrites, organic matter.
- Manufacture: preparation of clay → moulding (hand / machine) → drying → burning (clamp or kiln: Bull's trench, Hoffman).
- Standard (modular) brick size = 190 × 90 × 90 mm (nominal 200 × 100 × 100 mm with mortar).

➤ Tests on bricks

- **Compressive strength**: IS 1077 classes range from 3.5 to 35 MPa.
- **Water absorption**: about 20% max by weight (24 h immersion) for ordinary good bricks; lower for higher classes.
- **Efflorescence**: white salt patches; rated nil, slight, moderate, heavy, serious.
- Field tests: uniform colour, sharp edges, metallic ringing sound when struck, no scratch mark by finger nail.

➤ Other materials

- **Lime**: fat lime (high CaO, slakes fast, for plaster), hydraulic lime (sets under water, has clay). Lime cycle: limestone → quicklime (CaO) → slaked lime $Ca(OH)_2$ → sets by carbonation.
- **Timber**: seasoning reduces moisture (air seasoning, kiln seasoning); defects: knots, shakes, rind galls, twisted fibres; preservation: creosote, ASCU, chemical salts.
- Others: glass, paints (base, vehicle, pigment, thinner, drier), tiles, plastics, aluminium, steel.

3. Cement

- **OPC** made by burning limestone (calcareous) and clay (argillaceous) at about 1400 to 1500°C to form **clinker**, then grinding with gypsum (retards setting).
- Processes: dry process (modern, less fuel) and wet process (older).

➤ Oxide composition of OPC (approx.)

Oxide	%
Lime (CaO)	60 to 67
Silica (SiO2)	17 to 25
Alumina (Al2O3)	3 to 8
Iron oxide (Fe2O3)	0.5 to 6
MgO	under 6 (limited by code)

➤ Bogue compounds

Compound	Name	Role
C3S	Tricalcium silicate (alite)	Early strength (first 7 days), high heat
C2S	Dicalcium silicate (belite)	Later strength, low heat
C3A	Tricalcium aluminate	Flash set, highest heat, poor sulphate resistance
C4AF	Tetracalcium alumino ferrite	Little strength, colour

- Hydration of C3S and C2S gives **C-S-H gel** (main strength) and Ca(OH)2.

➤ Types of cement

Cement	Use / feature
OPC 33 / 43 / 53	General works (number = 28-day strength in MPa)
PPC (with fly ash / pozzolana)	Mass concrete, marine works, less heat
PSC (with GGBS)	Marine works, sulphate exposure
Rapid hardening	Early strength (high C3S, finer)
Sulphate resisting	Low C3A; foundations in sulphate soils
Low heat	Low C3A and C3S; dams
White cement	Very low iron oxide; decoration

➤ Tests on cement

- **Fineness**: Blaine air permeability (specific surface; OPC ≥ 225 m^2/kg) or sieve test.
- **Normal consistency**: Vicat plunger penetrates to 5 to 7 mm from the bottom of the mould (usually 26 to 33% water).
- **Setting time** (Vicat): initial ≥ 30 min, final ≤ 600 min for OPC.
- **Soundness**: Le Chatelier (expansion ≤ 10 mm, due to free lime) and autoclave (≤ 0.8%, due to MgO).
- **Compressive strength**: 70.6 mm mortar cubes (1:3 cement : standard sand) tested at 3, 7, 28 days.

4. Aggregates and Water

- Fine aggregate: passes 4.75 mm sieve. Coarse aggregate: retained on 4.75 mm.
- Shape: rounded (good workability), angular (better bond, more water). Flaky and elongated particles are bad.
- **Fineness modulus (FM)** = sum of cumulative % retained on standard sieves (down to 150 μm) / 100.

EXAMPLE Cumulative % retained: 4.75 mm 2, 2.36 mm 10, 1.18 mm 30, 600 μm 55, 300 μm 80, 150 μm 96. Sum = 273. FM = 273/100 = 2.73 (medium sand).

- FM of sand: fine about 2.2 to 2.6, medium 2.6 to 2.9, coarse 2.9 to 3.2.
- IS 383 divides sand into **grading zones I to IV** (zone I coarsest, zone IV finest).
- **Bulking of sand**: damp sand occupies more volume (surface films of water). Max bulking at about 4 to 6% moisture; saturated sand shows no bulking.
- Aggregate tests: crushing value, impact value, Los Angeles abrasion, specific gravity and water absorption, flakiness and elongation.
- Water: potable water is generally fit for mixing; pH ≥ 6 (IS 456).

5. Fresh Concrete

- **Workability** = ease of mixing, placing, compacting and finishing without segregation.

Test	Suitable for
Slump test	Medium to high workability (most common on site)
Compaction factor	Low workability (more sensitive)
Vee-Bee consistometer	Very low workability (lab)
Flow table	High workability
Slump flow, L-box, V-funnel	Self-compacting concrete

- Slump types: true slump (good), shear slump (lack of cohesion), collapse slump (too wet).
- **Segregation**: separation of coarse aggregate from mortar. **Bleeding**: water rising to the top surface (forms laitance).
- Factors for workability: water content, aggregate size / shape / grading, admixtures, temperature.

➤ Admixtures

- **Chemical**: plasticisers, superplasticisers (high water reduction), retarders (hot weather, long haul), accelerators (CaCl2, not for RCC due to corrosion), air-entraining agents (freeze–thaw).
- **Mineral**: fly ash, GGBS, silica fume (very fine, high strength), metakaolin, rice husk ash. They react with Ca(OH)2 to make extra C-S-H (pozzolanic reaction).

6. Hardened Concrete

- **Abrams' law**: strength depends on water–cement ratio (lower w/c → higher strength), provided the concrete is fully compacted.
- **Gel–space ratio** (Powers) is a better measure of strength.
- **Curing** keeps moisture and temperature for hydration: ponding, wet covering, membranes, steam curing. IS 456 suggests at least 7 days for OPC.
- **Maturity** = Σ (time × temperature above −10°C); used to estimate strength.

➤ Strength tests

- Compressive strength: 150 mm cubes at 28 days (IS 516). Cylinder strength ≈ 0.8 × cube strength.
- Split tensile (cylinder) and flexural strength (beam, two-point loading).

FORMULA Flexural strength fcr = 0.7 sqrt(fck). Ec = 5000 sqrt(fck) (IS 456).

➤ Durability

- **Creep**: strain increase under sustained load. **Shrinkage**: volume loss on drying (plastic, drying, autogenous, carbonation).
- Attacks: sulphate (expansion), chloride (steel corrosion), carbonation (lowers pH, depassivates steel), alkali–aggregate reaction (expansive gel).
- Protection: low w/c, enough cover, good compaction, proper curing, suitable cement.

➤ Non-destructive tests

- **Rebound hammer**: surface hardness → approximate strength. **Ultrasonic pulse velocity (UPV)**: uniformity, cracks, voids. Core cutting gives direct strength (partly destructive).

7. Concrete Mix Design (IS 10262)

- Aim: find proportions of cement, water, fine and coarse aggregate for required strength, workability and durability at lowest cost.
- Nominal mix (fixed ratios like 1:2:4) vs design mix (based on tests). IS 456 allows nominal mix up to M20 only.

FORMULA Target mean strength $f'ck = fck + 1.65\ s$ (s = standard deviation; about 4 MPa assumed for M20 and M25).

➤ Steps

1. Find target mean strength.
2. Choose w/c ratio from strength curve; check max w/c for exposure (IS 456).
3. Choose water content for the slump and max aggregate size; adjust for admixture.
4. Cement content = water / (w/c); check min cement content for exposure.
5. Find volume of coarse aggregate from FM / zone of sand; then fine aggregate by absolute volume.
6. Trial mixes and adjustment.

EXAMPLE M25, $s = 4$ MPa. $f'ck = 25 + 1.65 \times 4 = 31.6$ MPa. If water = 186 kg/m³ and w/c = 0.45, cement = 186/0.45 = 413 kg/m³.

EXAMPLE Nominal mix 1:2:4 for 1 m^3 of concrete. Dry volume = 1.54 m^3. Cement = 1.54/7 = 0.22 m^3 x 1440 kg/m^3 = 317 kg (about 6.3 bags of 50 kg). Sand = 0.44 m^3, coarse aggregate = 0.88 m^3.

8. Special Concretes

Concrete	Feature
Ready-mix concrete (RMC)	Made in a plant, delivered by transit mixers
Self-compacting (SCC)	Flows and fills formwork without vibration
High-performance (HPC)	High strength and durability, low w/c, silica fume
Fibre-reinforced (FRC)	Steel / polymer / glass fibres improve crack control
Light-weight	Light aggregate or foam; insulation
Polymer concrete	Polymer binder; fast setting, chemical resistance
Shotcrete	Sprayed concrete; tunnels, slope protection
Prestressed concrete	High-strength concrete and steel; compression applied before loading

9. Most Asked Questions (practice)

1. List qualities of a good building stone and tests on stones.
2. Explain composition of brick earth and tests on bricks.
3. Describe manufacture of OPC; give its oxide composition.
4. Explain Bogue compounds and their roles in hydration.
5. Explain tests on cement: consistency, setting time, soundness, fineness.
6. Find the fineness modulus of sand from sieve data; explain bulking of sand.
7. Explain workability tests and factors affecting workability.
8. Explain types of admixtures with examples.
9. Explain creep, shrinkage and durability problems of concrete.
10. Design a concrete mix by IS 10262 for given data.

TIP GATE CE asks Bogue compounds, cement tests (setting time, soundness limits), FM calculation, w/c ratio, target mean strength and NDT. Learn the numbers in the tables above well.