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NEPAL ENGINEERING COUNCIL
LICENSE EXAM PREPARATION COURSE

FOR

CIVIL ENGINEERS

5. Design of Structure

5.2 Concrete technology

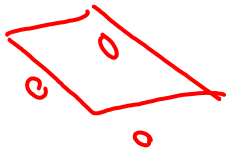
Sub topics

- Materials — Cement, FA (Sand), CA (Gravel), water, admixture
- Properties
- Mix design →
- Testing →
- Quality control ~

Concrete Technology

Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time.

Concrete technology deals with study of properties of concrete and its practical applications.



Materials

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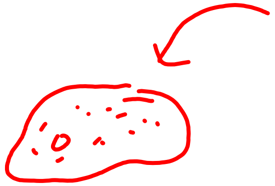
Cement:
A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together.

Water:
It helps in binding all the components.

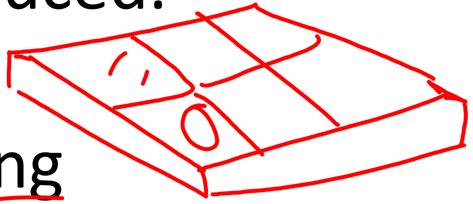
Fine and coarse aggregate:
It provides body to concrete. 60-75% of volume.

Concreting Process



Batching

The first step involves gathering the ingredients necessary to produce the particular type of concrete. The type of batching, volume or weighted, is contingent on the amount of concrete being produced.



Mixing

Depending on the type and quantity needed for a particular job, concrete can be mixed by hand, by stationary mixer, or during transport. Regardless of how it is mixed, the critical point is to ensure the concrete is uniform in color and consistency for optimal setting.

Concreting Process

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Transporting and Placing

Methods of transporting concrete vary widely from wheelbarrow and manual hauling to conveyor belt operations, to more advanced projects involving cranes and pumps.

Compacting and Placing

During mixing and transport air is often entrapped, greatly reducing the quality and strength. One of the final stages of production involves compacting the product to eliminate the air pockets and ensure durability.

Concreting Process

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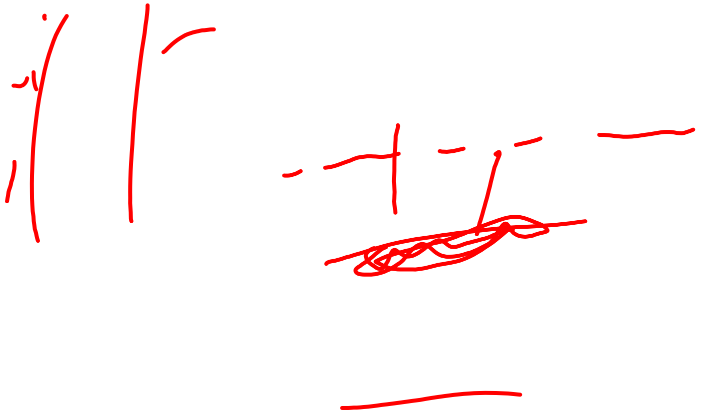
Curing and Finishing

This process takes place immediately after concrete is compressed and involves close attention to detail regarding moisture levels and contracting as it dries. This process is crucial in preventing cracking and durability issues.



Grade of concrete

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Ordinary grade: → Nominal mix

M10 - M20

IS 456

Standard grade: → Mix design

M25 - M60

1:1:2

High Strength:

M65 or more ← experimentally desingh

Mix Design

Nominal mix

M20 → 20N/mm² 20 MPa → 28 day

cement 1 : 1.5 : 3 → CA → volume

FA

CA : FA ≈ 2 : 1

1m³ + 1.5 m³ + 3m³ = 5.5m³

→ weight to weight

$W/C = \frac{30}{50} = 0.6$

Grade of concrete	Total quantity of dry aggregate by mass per 50 kg of cement to be taken as the sum of the individual masses of fine and coarse aggregates	Proportion of fine aggregate to coarse aggregate (by mass)	Maximum quantity of water per 50 kg of cement	Proportion
M5	800	Generally, 1:2 but subject to an upper limit 1:1½ and a lower limit of 1: 2½	60	1:5:10
M7.5	625		45	1:4:8
M10	480		34	1:3:6
M15	330		32	1:2:4
M20	250		30	1:1.5:3

M25 28 1:1:2

$\frac{5.5\,m^3}{1.54}$ = wet volume

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Mix Design

Volume of dry mixture is 54% more than wet concrete.

- 1.54 cubic meter of dry concrete mix makes 1 cubic meter of wet concrete.

$0.4 \times 1.54 = 0.62\,m^3$

C FA CA

$0.2 \times 0.4 \times 5 = 0.4$

Ratio of nominal mix is based on volume of constituents

- 500mm Volume of cement : volume of fine agg : volume of coarse agg

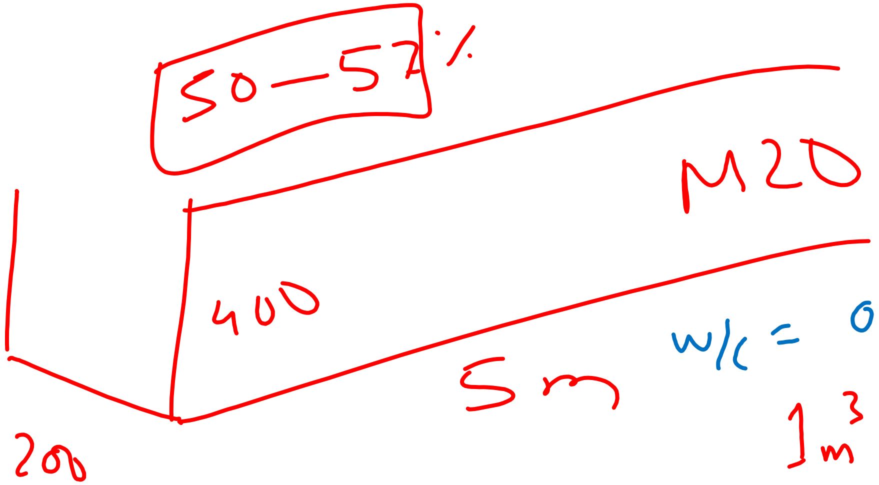
200 400

Density of cement : $1440\ kg/m^3$, sp gr :3.15

$V = 0.4\,m^3$ Wet volume

Density of F A : $1600\ kg/m^3$

Density of C A : $2500\ kg/m^3$



$M20 = 1 : 1.5 : 3$

$1 + 1.5 + 3 = 5.5$

$w/c = 0.6$

$1440\ kg/m^3$

$1\ m^3$ cement → 28.8 bag

10% increase

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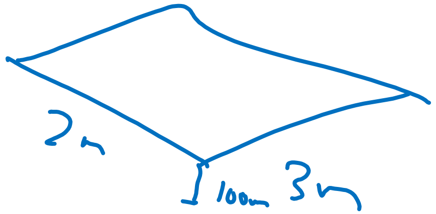


Wet volume $= 0.2 \times 0.4 \times 5 = 0.4\ m^3$

Dry volume $= 1.54 \times 0.4 = 0.62\ m^3$

→ Volume of cement $= \frac{1}{5.5} \times 0.62 = 0.113\ m^3$

Volume of FA $= \frac{1.5}{5.5} \times 0.62 = 0.17\ m^3$ (1600–1800 kg/m^3)

Vol of CA $= 0.34\ m^3$ (2400–2500)

3 0 3 → 3

S

→ sp gr → 3.15

kg → $1440 \times 0.113 = 163$ kg

bag → $163/50 = 3.25$ bags

water $= 0.6 \times 163 = 98$ kg $= 98$ l

$V = 2 \times 3 \times 0.1$

$= 0.6\ m^3$

$V = 0.6 \times 1.1 = 0.66$

Mix Design

Volume of dry mixture is 33% more than wet mortar.

- 1.33 cubic meter of dry mortar mix makes 1 cubic meter of wet mortar.

1 : 6 → 2m x 3m 12mm

2x3x0.012 =

Ratio of nominal mix is based on volume of constituents

- Volume of cement : volume of fine agg

Density of cement : 1440 kg/m^3 , sp gr :3.15

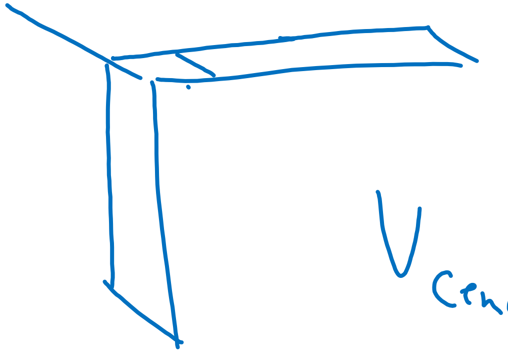
Density of F A : 1600 kg/m^3

2m × 3m × 280mm   plaster → 12mm thick

(1:6)   Cement required ?

7

$V_{wet} = 2 \times 2 \times 3 \times 0.012 = 0.144\,m^3$



$V_{Dry} = 1.33 \times 0.144 = 0.192$

$V_{cement} = \frac{1}{7} \times 0.192 = 0.027\,m^3$

Kg $0.027 \times 1440 = 38$

$V_{sand} = 6 \times 0.027\,m^3$

Mix Design

Design mix

1. **IS Method –** Concrete mix proportioning guidelines (Bureau of Indian Standards – I.S. 10262- 2009) and Recommended Guidelines for Concrete Mix Design- I.S. 10262- 2009,

2. **BS Method –** (British Standard – BS EN 206- 1 and its complementary standards BS 8500 parts 1& 2)

3. **ACI Method –** (American Standard – ACI 211, 211- 91, reapproved- 2002).

Mix Design

M 25 ↗ 10-15 | 3.5
20-25 | 4
higher | 5

Procedure for Concrete Mix Design – IS456:2000

1. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day f_{ck} and the level of quality control.

$$f_t = f_{ck} + 1.65\, S = 25 + 1.65 \times 4 = 31.6 \text{ N/mm}^2$$

25 → 35

Where, S is the standard deviation obtained from the Table of approximate contents given after the design mix.

2. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.

3. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

Mix Design

4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.

5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.

6. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.

7. Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.

Mix Design

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8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

Where, V = absolute volume of concrete = gross volume ($1 m^3$) minus the volume of entrapped air

S_c = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

p = ratio of fine aggregate to total aggregate by absolute volume

fa, Ca = total masses of fine and coarse aggregates, per cubic metre of concrete, respectively, kg, and

S_{fa}, S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates, respectively

Mix Design

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9. Determine the concrete mix proportions for the first trial mix.

10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.

11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

Concrete

Initial concrete is plastic and it hardens with time.

Short term requirement: Workability, no bleeding, no segregation

Long term requirement: Strength, durability, no permeability, volume stability

Fresh Concrete

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1. Be easily mixed and transported.
2. Be uniform throughout a given batch and between batches.
3. Be of a consistency so that it can fill completely the forms for which it was designed.
4. Have the ability to be compacted without excessive loss of energy.
5. Not segregate during placing and consolidation.
6. Have good finishing characteristics.

Workability

Water content: Workability increases on increasing water content

Aggregate mix proportion: Workability increases on decreasing fine aggregate proportion as it reduces surface area.

Shape of aggregate: Rounded aggregate increases workability

Time and Temperature: In general, increasing temperature will cause an increase in the rate of hydration and evaporation. Both of these effects lead to a loss of workability.

Admixtures: Air-entraining, water-reducing, and set-retarding admixtures will all improve workability.

Admixtures

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Air entrainers: Natural wood resin, plant and animal fatty oil, stearic acid, oleic acid, hydrogen peroxide, aluminium powder

Plasticizers (8-15% reduction): lignosulphate, polyglycol ester, carbohydrates, hydroxylated carboxylic acid

98

Super Plasticizers (15-30% reduction): Sulfonated Melamine formaldehyde resin, sulfonated naphthalene-formaldehyde resin, Mixtures of saccharates, and acid amides. modified lignosulphonate

Set Retarders: Gypsum, Sugar

Set Accelerators: calcium chloride, silicates, flousilicate

Segregation

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Segregation refers to a separation of the components of fresh concrete, resulting in a nonuniform mix. This can be seen as a separation of coarse aggregate from the mortar, caused from either the settling of heavy aggregate to the bottom or the separation of the aggregate from the mix due to improper placement.

Some factors that increase segregation are:

1. ↑ Larger maximum particle size (25mm) and proportion of the larger particles.
2. ↑ High specific gravity of coarse aggregate.
3. ↓ Decrease in the amount of fine particles.
4. Particle shape and texture.
5. Water/cement ratio. ↑

Bleeding

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Bleeding is defined as the appearance of water on the surface of concrete after it has consolidated but before it is set.

Bleeding may be reduced by:

1. Increasing cement fineness.
2. Increasing the rate of hydration.
3. Using air-entraining admixtures.
4. Reducing the water content.

Measurement of workability/consistency

rich mixes ⇒

Slump Test –

- **Shape**: A frustum of a cone
- **Bottom Diameter**: 20 cm
- **Top Diameter**: 10 cm
- **Height**: 30 cm

Each layer is rodded with a 16mm steel rod 25 times. The slump test is a measure of the resistance of concrete to flow under its own weight.

For medium to high workabilities/ slump in range of 25-125 mm is required.

Measurement of workability/consistency

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Slump Test –

Placing Conditions	*Degree of Workability*	*Slump* (mm)
(1)	(2)	(3)
Blinding concrete; Shallow sections; Pavements using pavers	Very low	*See* **7.1.1**
Mass concrete; Lightly reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining; Strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns;	Medium	50-100
Slipform work; Pumped concrete		75-100
Trench fill; *In-situ* piling	High	100-150
Tremie concrete	Very high	*See* **7.1.2**

Measurement of workability

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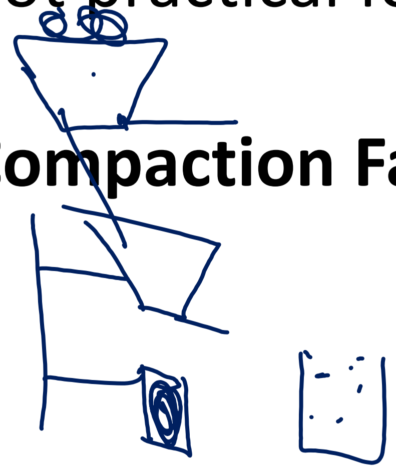
low workability

Compaction Test –
Concrete strength is proportional to its relative density. It involves dropping a volume of concrete from one hopper to another and measuring the volume of concrete in the final hopper to that of a fully compacted volume. This test is difficult to run in the field and is not practical for large aggregates (over 1 in.).



empty vessel

Compaction Factor Value= (W1-W) / (W2-W)

initial wt

compacted wt

Measurement of workability

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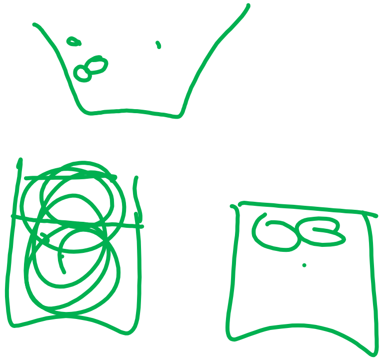
Compaction Test –



Degree of Workability	Compaction Factor
Very Low	0.78 - 0.80
Low	0.80 - 0.85
Medium	**0.85 - 0.95**
High	0.95 - 1.00

normal wt / compressed wt

Medium workabi comp.

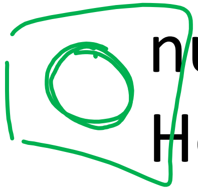
b) 0.92

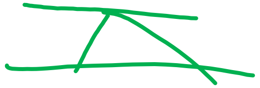
c) 0.95

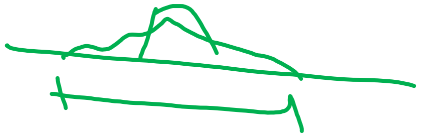
Measurement of workability

→ very low workability

Flow Test -- Measures a concretes ability to flow under vibration and provides information on its tendency to segregate. There are a number of tests available but none are recognized by ASTM. However, the flow table test described for mortar flows is occasionally used.







fiber mixed concrete

Vebe Test - A standard slump cone is cast, the mould removed, and a transparent disk placed on top of the cone. The sample is then vibrated till the disk is completely covered with mortar. The time required for this is called the Vebe time. For slump less than 75 mm

Setting of concrete

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Setting is defined as the onset of rigidity in fresh concrete. Hardening is the development of useable and measurable strength; setting precedes hardening.

C_3A, C_2S, C_3S, C_4AF

↳

Early setting C_3A - Celite

Early strength C_3S - Alite

Late strength C_2S → Belite

Tests of Fresh Concrete

Workability
Time of Setting
Air Content

Hardened Concrete

Strength is defined as the ability of a material to resist stress without failure.

The strength is the property generally specified in construction design and quality control, for the following reasons:

(1) It is relatively easy to measure, and

(2) Other properties are related to the strength and can be deduced from strength data.

Characteristic stress f_{ck}

The 28-day compressive strength of concrete determined by a standard uniaxial compression test

100kN

Failure of Hardened Concrete

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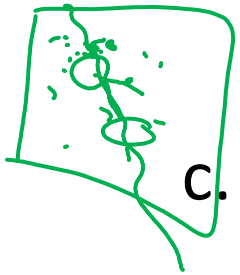

a. At about 25-30% of the ultimate strength, random cracking (usually in transition zone around large aggregates) are observed
b. At about 50% of ultimate strength, cracks grow stably from transition zone into paste. Also, microcracks start to develop in the paste.
c. At about 75% of the ultimate strength, paste cracks and bond cracks start to join together, forming major cracks. The major cracks keep growing while smaller cracks tend to close.
d. At the ultimate load, failure occurs when the major cracks link up along the vertical direction and split the specimen

NDT- non destructive tests

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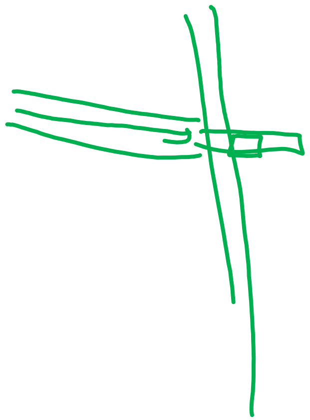
- Penetration test

  The Windsor probe is generally considered to be the best means of testing penetration. Equipment consists of a powder-actuated gun or driver, hardened alloy probes, loaded cartridges, a depth gauge for measuring penetration of probes and other related equipment.



NDT- non destructive tests

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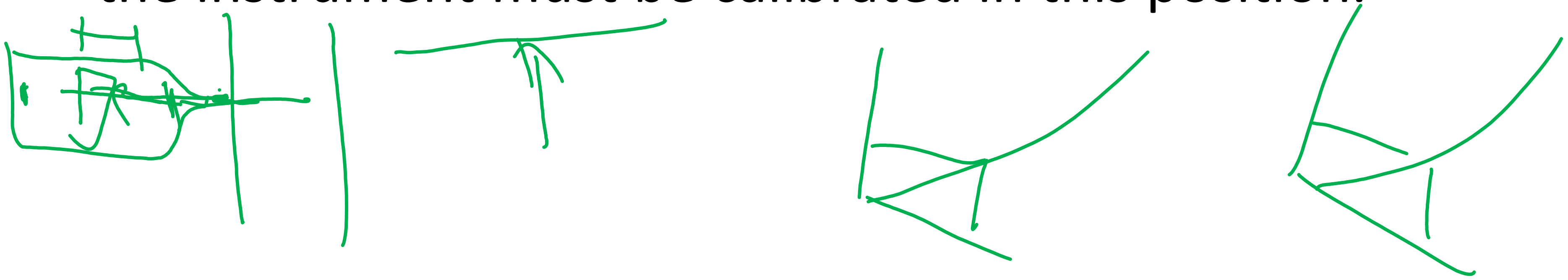
Rebound Hammer Method

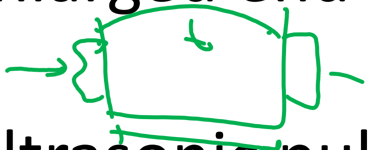
The rebound hammer is a surface hardness tester for which an empirical correlation has been established between strength and rebound number. The hammer is forced against the surface of the concrete by the spring and the distance of rebound is measured on a scale. The test surface can be horizontal, vertical or at any angle but the instrument must be calibrated in this position.



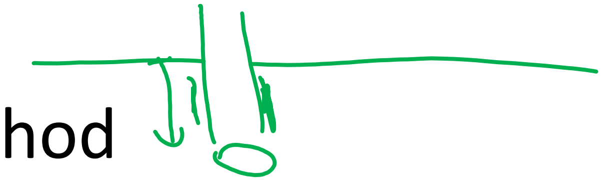
NDT- non destructive tests

Pull-Out Test

A pull-out test measures, with a special ram, the force required to pull from the concrete a specially shaped steel rod whose enlarged end has been cast into the concrete to a depth of 3 in



$L/t = V$



Ultrasonic pulse velocity method

Pulses are generated by shock-exciting piezoelectric crystals, with similar crystals used in the receiver. The time taken for the pulse to pass through the concrete is measured by electronic measuring circuits. Above 3500m/s is considered good.

Compressive Strength test (IS 516-1959)

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Cubical specimen dimension: 15x15x15 cm

Cylindrical specimen dimension: diameter 15 cm, height 30 cm

Atleast 3 specimen required, Rate of loading is 14 N/mm^2 per minute

M20

0.16x20
3.2 MPa

0.4x20=8MPa

Age	Strength percent
1	16%
3	40%
7	65%
14	90%
28	99% ~100%

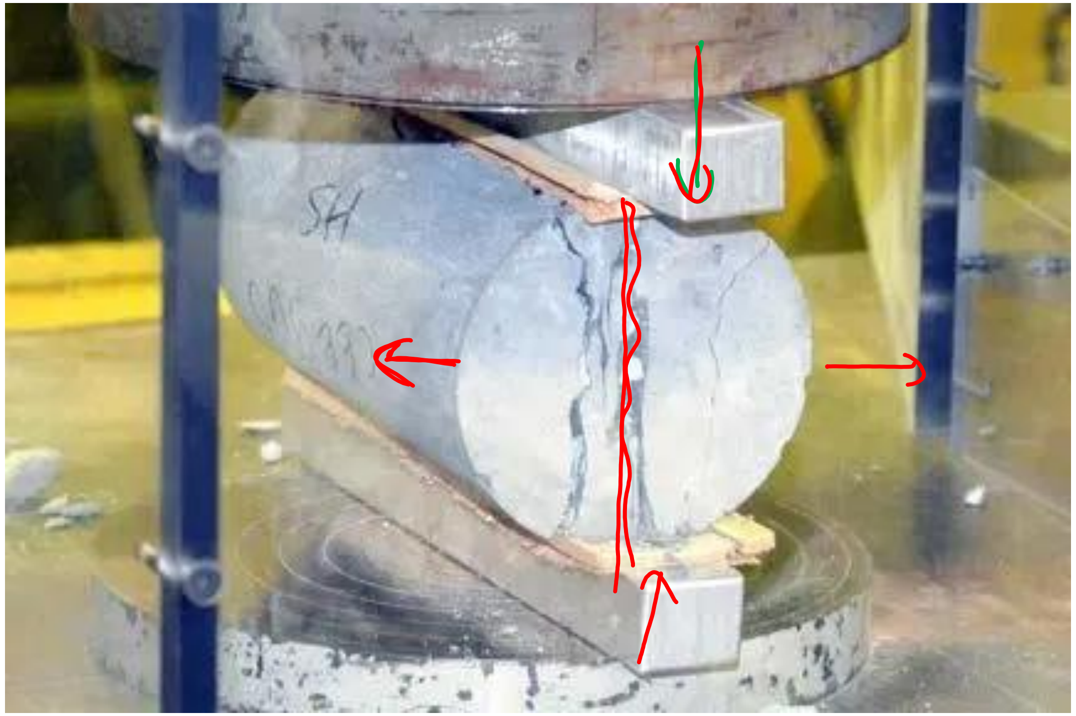
Splitting Tensile test (IS 5816-1999)

h/D = 2

Cylindrical specimen dimension: diameter 15 cm, height 30 cm

Atleast 3 specimen required, Rate of loading is 1.2-2.4 N/mm^2 per minute

$$T = \frac{2P}{\pi L D}$$



Flexural test (IS 516-1959)

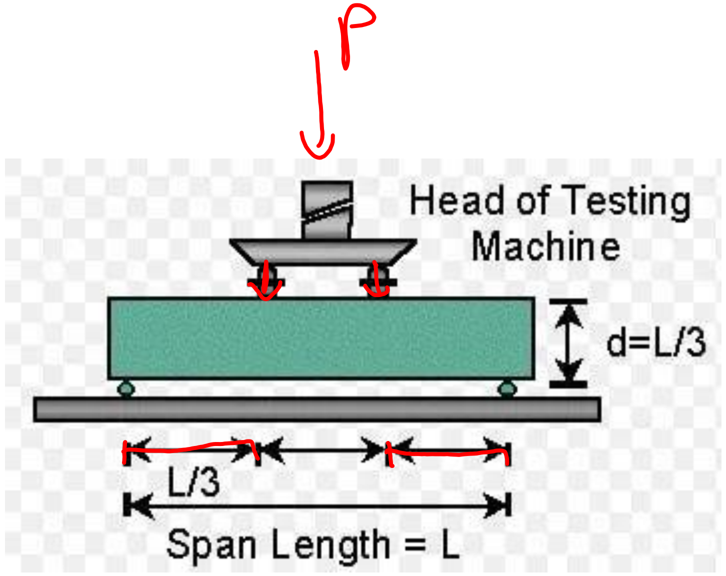
15x15x70 or 10x10x50 dimension beam

Atleast 3 specimen required, Rate of loading is 400 kg per minute and 180 kg /min

$\sigma = \frac{M}{Z} = \frac{Pl/8}{bd^2/6}$

Modulus of rupture

$$f_b = \frac{Pl}{bd^2}$$



Flexural test (IS 516-1959)

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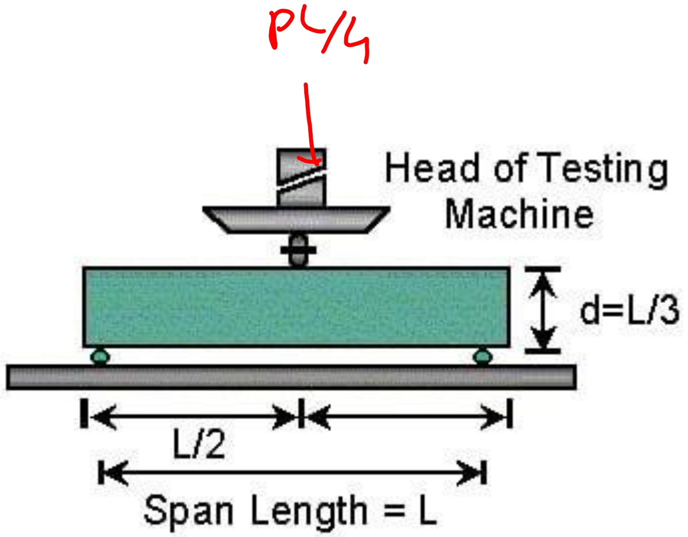
Modulus of rupture

$$f_b = \frac{3Pl}{2bd^2}$$

M25

$f_{cr} = 0.7\sqrt{25} = 3.5$ MPa $/N/mm^2$

$$f_{cr} = 0.7\sqrt{f_{ck}}$$



Drilled Core method:

Core is drilled and it is tested

Elasticity values (N/mm^2)

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2×10^5 N/m² }

Short term Modulus of elasticity or generally elasticity

25000 MPa

25 GPa

$$E = 5000\sqrt{f_{ck}}$$

Long term Modulus of elasticity

$$E_\theta = \frac{E}{1+\theta}$$

θ is creep strain coefficient

θ

Age of loading	θ
7 days	2.2
28 days	1.6
1 year	1.1

Quality control before concreting

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This stage of quality control consists of two steps.

a. Checking of specification requirements regarding excavation, forms, reinforcement and embedded fixtures etc.
b. Control test on concrete ingredients (i.e. on cement, aggregate & water)

The quality of concrete is affected by different physical and mechanical properties of aggregate, i.e. shape, grading, durability, specific gravity and water absorption etc. these properties of aggregated should be tested before using it for concrete production.

8.5

Water should be potable and ph should not be less than 6.

Quality control during concreting

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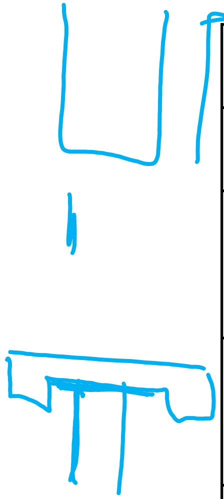
- Checks on workability, mixing quality
- Amounts and proportion being used to make concrete
- Checks on form works
- Checks on use of admixtures

Quality control after concreting

- Optimum curing
- Various testing

Striking after concreting

The process of removal of formwork or shuttering in the process of casting concrete is known as striking.



Type of formwork	Minimum period before striking
Vertical formwork to columns beam walls	16-24 hr – 28
Soffit formwork to slab (props to be refixed immediately)	3 days
Soffit formwork to beam (props to be refixed immediately)	7 days
Props to slab spanning upto 4.5 m	7 days
Props to slab spanning over 4.5 m	14 days
Props to beam/arches spanning upto 6 m	14 days
Props to beam/arches spanning over 6 m	21 days

Which of the following ratio is also known as water-cement ratio?

a. Weight of water to the weight of aggregates

b. Density of cement to the Density of cement

c. Weight of water to the weight of cement

d. Volume of cement to the volume of cement

What is the total percentage of aggregates in concrete in terms of volume?

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a. 75 – 85%

b. 90%

c. 60-75%

d. 50%

Which of the following increases the workability of concrete?

a. Decreasing size of aggregates

b. Increasing flaky aggregates

c. Increasing size of aggregates

d. Increasing fine aggregates

The form work is usually removed after ________ for walls, columns, and the vertical faces of all structural components

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16- 24

a. 24 to 48 hours

b. 72 hours → 3 day → slab   prop refix

c. 7 days →

d. 14 days

Which of the following stress can Plain cement concrete endure?

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a. Shear stress

b. Tensile stress

c. Compressive stress

d. Tensile, compressive, and shear stresses

Which of the following is not a type of Non-destructive testing?

a. Ultrasonic test

b. Eddy current testing

c. Compression testing

d. Visual testing

Which of the following are standard grade concrete?

a. M10 –M20 Ordinary

b. M25- M60

c. Above M60 High strength

d. All of the above

If 1500 g of cement is required to have a cement paste 1875 g of normal consistency, the percentage of water is,

w/c

1875-1500=375gm

a. 20%

b. 25%

c. 30%

d. none

$$\frac{375}{1875} = 20\%$$

$$w/c = \frac{375}{1500} = 0.25$$

The degree of plasticity of fresh concrete mortar is called

PANA ACADEMY

a. Consistency

b. Workability

c. Segregation

d. Grouting

Flexural strength of M25 concrete is?

a. 3 MPa

b. 3.5 MPa $0.7\sqrt{f_{ck}}$

c. 5 MPa

d. 25 MPa

Elastic modulus of elasticity of M25 concrete is?

PANA ACADEMY

a. 25 MPa

b. 2500 MPa

c. 25 GPa

d. 2500 GPa

3

$5000\sqrt{f_{ck}}$

$5000 \times 5 = 25000$ MPa

PANA ACADEMY

Thank YOU !!!