CONCRETE TECHNOLOGY

تكنلوجيا الخرسانة 2

المرحلة الثالثة

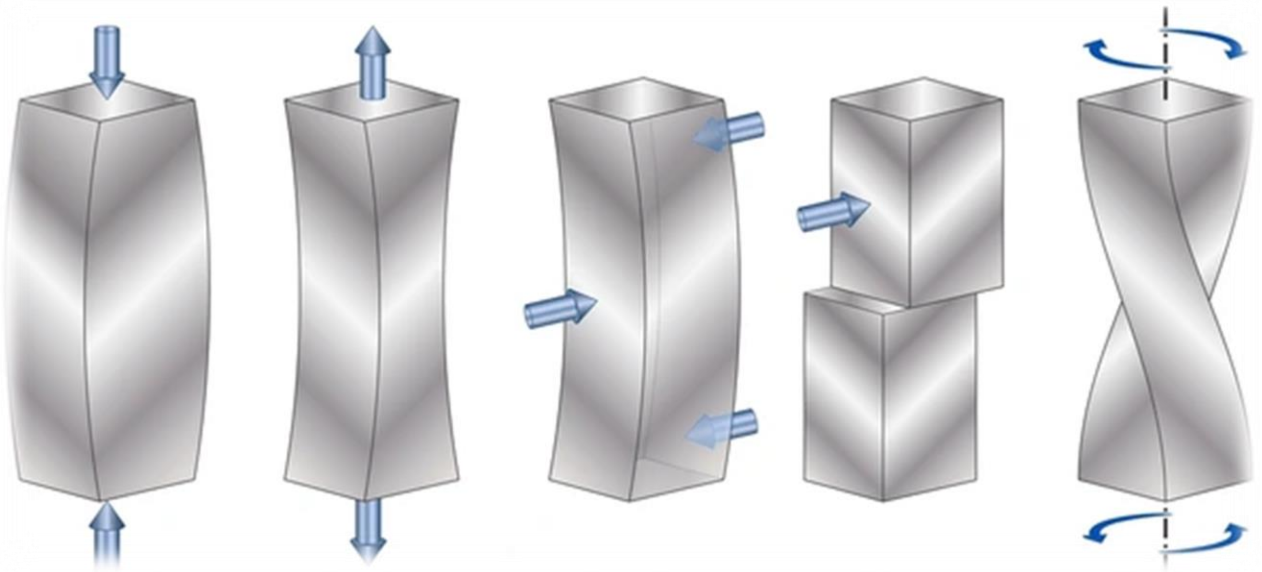
Asst. Lec. Nora AL-Anssari

Lecture 3:B

Hardened Concrete: Types of Strength

Types of Concrete Strength

- Compressive strength
- Tensile strength
- Shear strength
- Bond strength
- Impact strength
- Fatigue strength



1- Compressive Strength fc

- Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces.

- The compressive strength is used to determine the hardness of **cubical and cylindrical** concrete specimens.

- According to **(BS EN 12390-2011)**, The cube specimen is of the size **15 x 15 x 15 cm**. If the largest nominal size of the aggregate does not exceed 20 mm, **10 x 10 x 10 cm cubes** may also be used as an alternative .

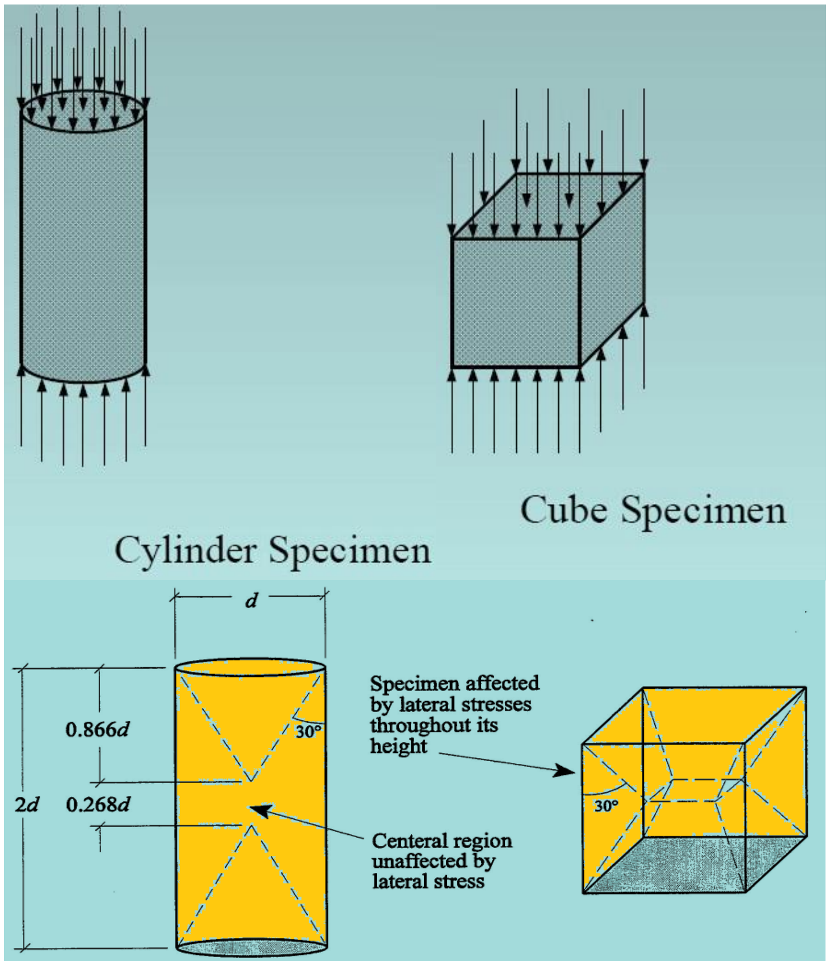
- According to **ASTM C39, Cylindrical** test specimens have a length equal to twice the diameter. They are **15 cm in diameter** and **30 cm long**.

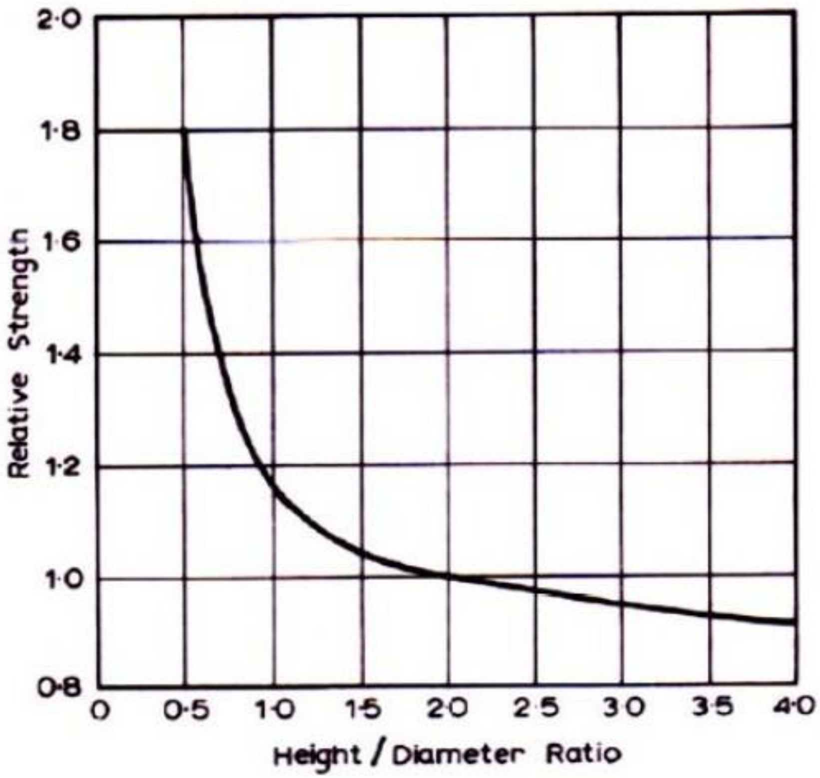
- The strength of cylinder is equal to 0.8 to 0.85 times of the strength of cubes.

$$\left(f_c\right)_{cylinder} = \left(0.85-0.80\right)\left(f_c\right)_{cube}$$

**Effect of Height/Diameter Ratio on Strength:

- Normally the height of the cylinder "h" is made twice the diameter "d", but sometimes, particularly, when **the core is cut from the road pavements or airfield pavements or foundations concrete**, it is not possible to keep the height/diameter ratio of 2:1. it is necessary to estimate the strength of the same concrete, as if it had been determined on a specimen with **h/d ratio equal to 2**.





**Specimens

- Before testing, neither end of test specimens shall depart from perpendicularity to the axis by more than 0.5°.
- The ends of compression test specimens that are not plane within 0.050 mm [0.002 in.] shall be sawed or ground to meet that tolerance, or capped.
- The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.25 mm [0.01 in.] by averaging two diameters measured at right angles to each other at about mid-height of the specimen.
- Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 %.

** Capping

- To decrease the amount of friction, capping of the rough casting surface is performed.
- Capping is the preparation of the ends of cylindrical concrete specimens to ensure that a test cylinder or core has smooth, parallel, uniform bearing surfaces that are perpendicular to the applied axial load during compressive strength testing.

Capping confirm specification (ASTM C 617) Capping Materials

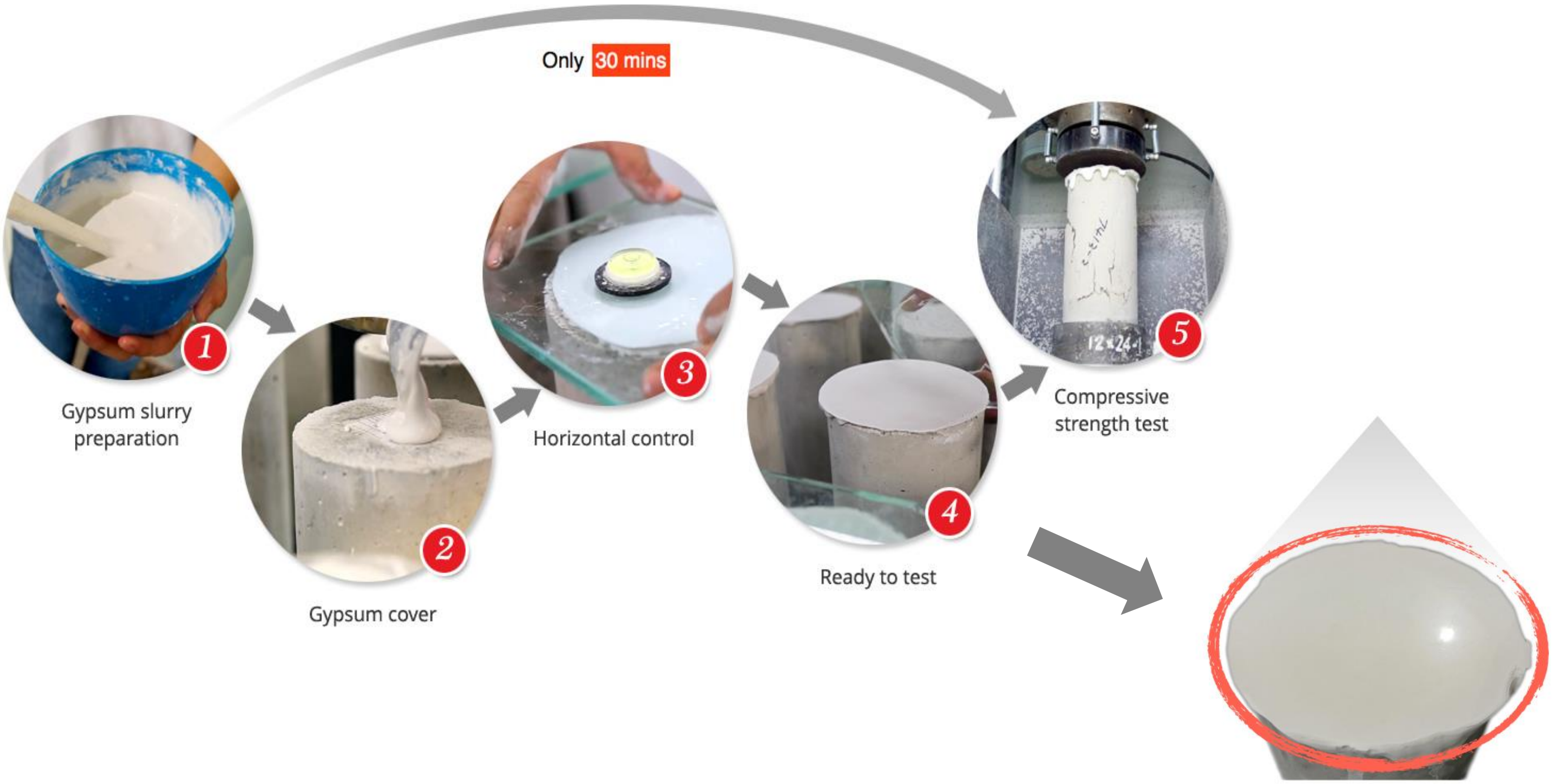
1. The Portland cement paste shall conform to the requirements of ASTM C150.
2. High-Strength Gypsum Slurry.
3. Sulphur Mortar (the best one).

** Capping procedure

Freshly Molded Cylinders : **Capping with Portland cement paste**

1. Use only neat Portland cement pastes.
2. Use a water-cement ratio of 0.32 to 0.36 by weight.
3. Apply the neat paste to the exposed end 24 h after moulding.
4. Mix the neat paste to a stiff consistency 2 to 4 h before it is to be used.

Capping with Gypsum Slurry:



** Capping procedure

Capping with Sulphur Mortar:

1. Sulphur mortar for use by heating to about 130 C.
2. The capping plate or device should be warmed slightly.
3. Oil the capping plate lightly.
4. To ensure that the cap shall be bonded to the surface of the specimen.

** Failure Mechanism

- There are three failure modes in uniaxial compression test shown below for cylinders and cubes.

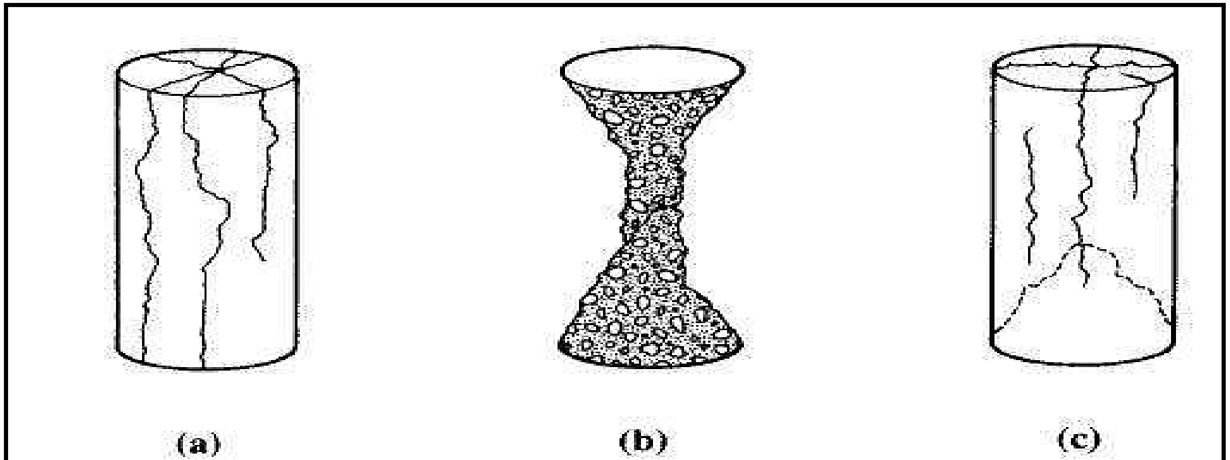
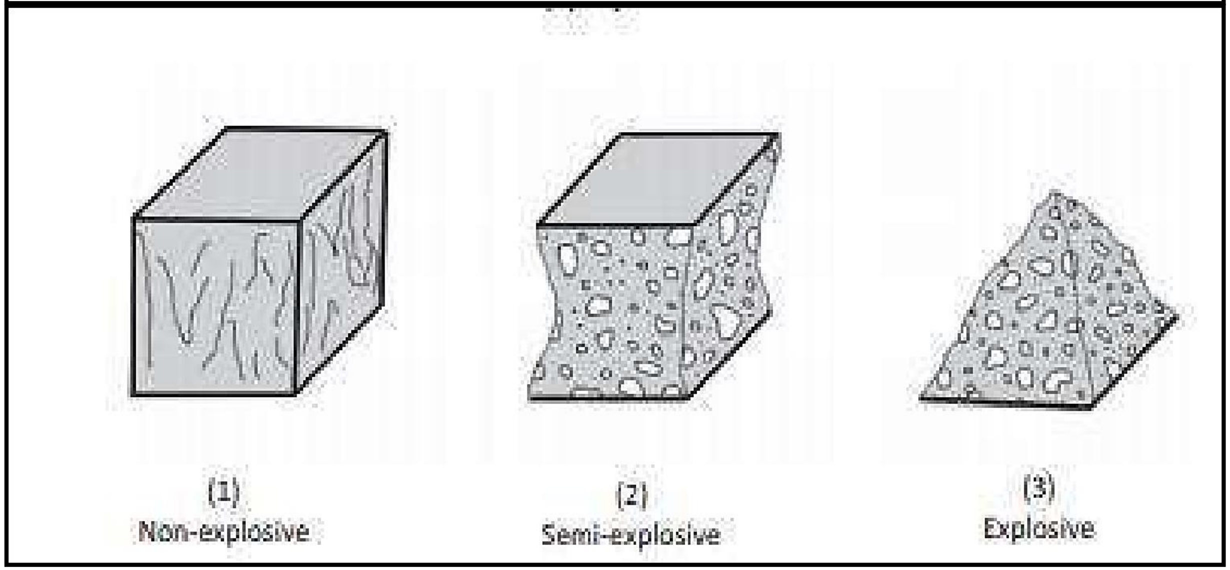


Fig. 16.2: Typical failure modes of standard test cylinders; (a) splitting, (b) shear (cone), and (c) splitting and shear (cone)



** Effect of steel plates of testing machine in compressive testing:

- In compression test, a tangential force is developed between the end surfaces of the concrete specimen and the adjacent steel plates of the testing machine.
- These forces will cause lateral expansion in concrete.
- The steel platen restrains the lateral expansion of the concrete in the parts of the specimen near its end.
- The degree of restraint exercised depends on the friction actually developed.
- When the friction is eliminated by applying grease, graphite or paraffin wax to the bearing surfaces, the specimen exhibits a larger lateral expansion and eventually splits along its full-length
- The compressive strength of concrete can be calculated by the ratio of failure load to surface area of the specimen:

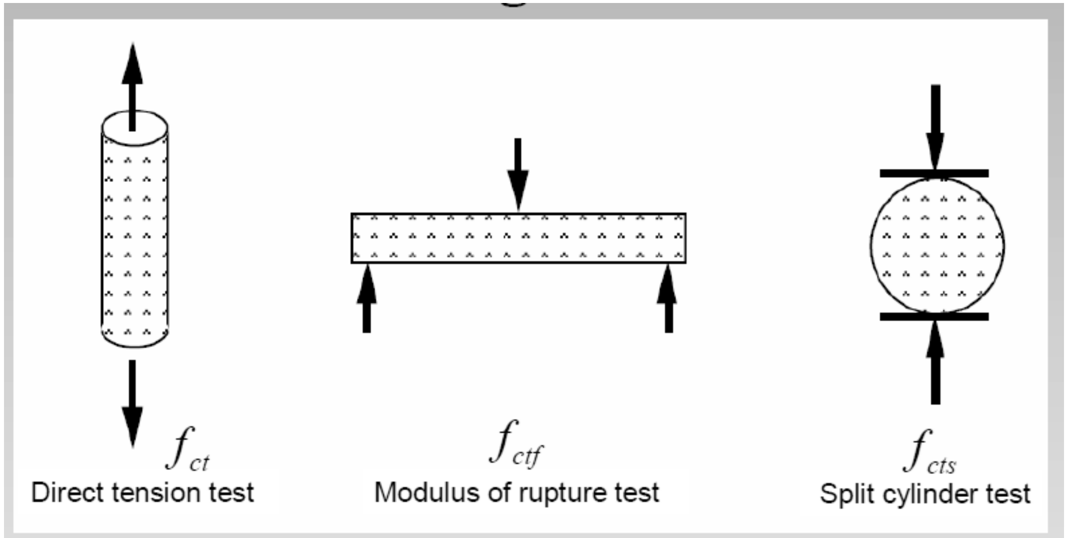
$$\text{Compressive Strength of Concrete} = \frac{\text{Max Load Carried by Specimen}}{\text{Top Surface Area of Specimen}}$$

2- Tensile Strength of Concrete

- The tensile strength of concrete is **much lower** than the compressive strength, largely because of the ease with which cracks can propagate under tensile loads, Although concrete is not normally designed to resist direct tension.

- The tensile strength of concrete is measured in three ways: **direct tension, splitting tension, and flexural tension (modulus of rupture)**.

- Direct tensile strength of concrete is difficult to determine; recourse is often taken to the determination of flexural strength or the splitting tensile strength and computing the direct tensile.

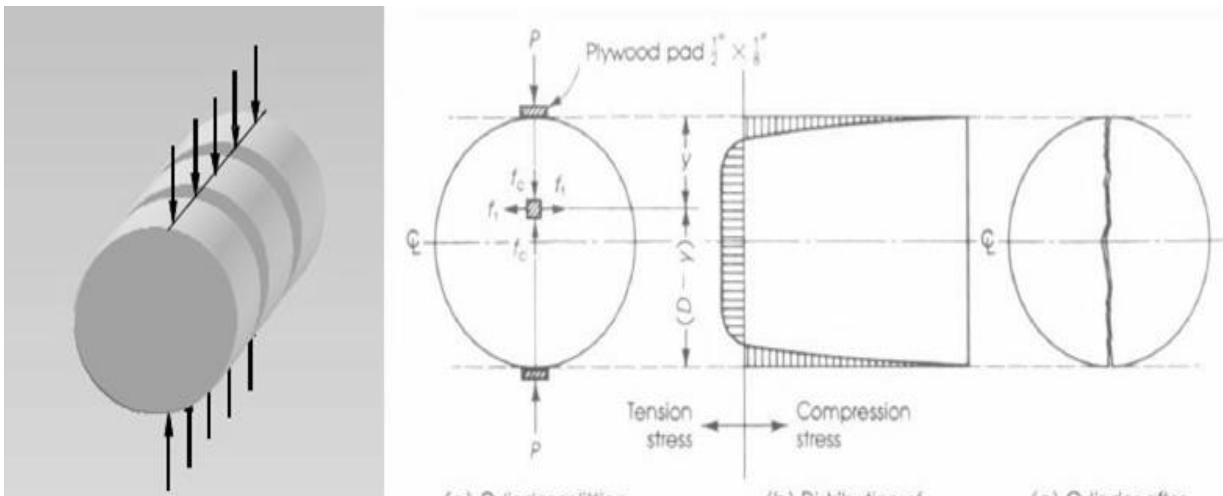


$$f_{ctf} > f_{cts} > f_{ct}$$

Split Tensile Strength Test (f_{cts})

- In this test, a concrete cylinder, of the type used for compression tests, is placed with its axis horizontal between the platens of a testing machine, and the load is increased until failure by indirect tension in the form of splitting along the vertical diameter takes place.

- However ,immediately under the load ,a high compressive stress would be induced and ,in practice ,narrow strips of a packing material ,such as plywood ,are interposed between the cylinder and the platens as shown in the Figure below



15cm × 30cm cylinder specimen

$$f_{cts} = \frac{2P}{\pi L D}$$

Where:

fcts **:** Splitting tensile strength, Mpa

P : Maximum applied load indicated by testing machine, N

L : Length, mm

D : Diameter, mm

The strength determined in the splitting test is believed to be close to the direct tensile strength of concrete, being 5 to 12 % higher.

Flexural strength (f_{ctf})

- It is also known as **modulus of rupture**, **bend strength**, or **fracture strength**, a mechanical parameter for brittle material, is defined as **a material's ability to resist deformation under load.**
- The flexural strength represents the highest stress experienced within the material at its moment of rupture.
- Flexural test evaluates the tensile strength of concrete **indirectly**.
- It tests the ability of **unreinforced concrete** beam or slab to withstand failure in bending.
- The results of flexural test on concrete expressed as a modulus of rupture which denotes as (f_r) or (f_{ctf}) in MPa or psi.

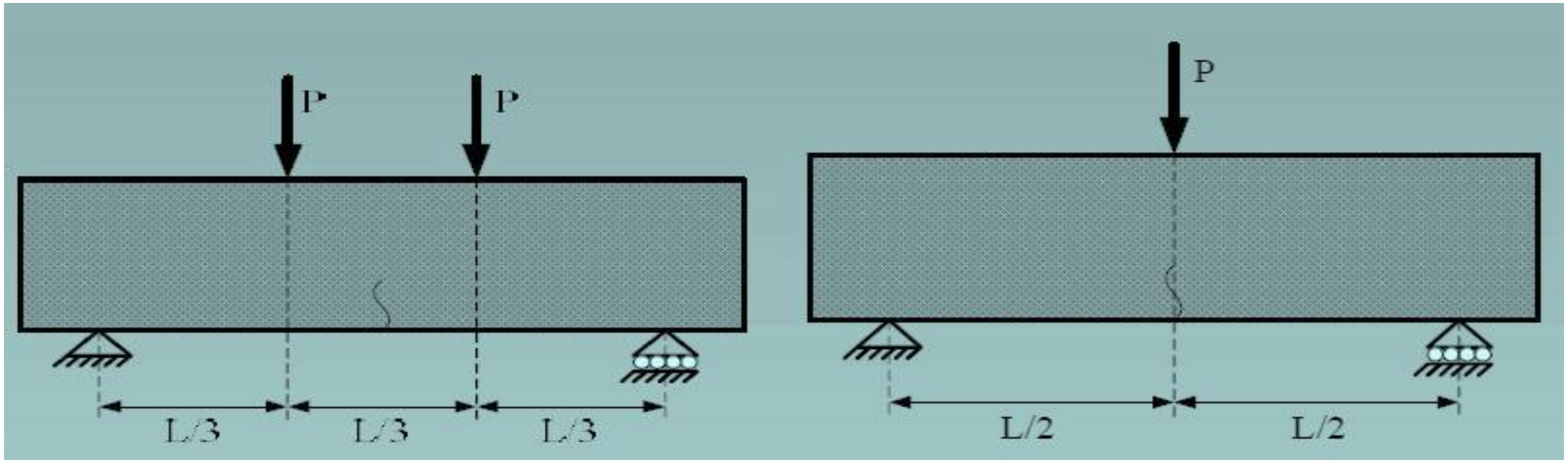
Types of Flexural Testing

Two main flex tests, namely **three points** and **four points** tests, are available:

- ➢ 3-Point Loading is simpler and easier to set up but may yield slightly lower flexural strength values because it focuses the maximum stress at a single point.
- ➢ 4-Point Loading is more complex but provides a more representative measure of the concrete's flexural capacity by distributing the stress, which often results in higher flexural strength values compared to 3-point loading.

The choice between three-point and four-point loading depends on testing standards and the specific requirements of the concrete structure being analyzed.

- three-point load test (ASTM C78) or center-point load test (ASTM C293) as shown below.



- If fracture occurs, the modulus of rupture is calculated on the basis of elastic theory, and is thus equal to:

- **3-Point Loading Flexural Strength**:
  $$f_{ctf} = \frac{PL}{bd^2}$$
- **4-Point Loading Flexural Strength**:
  $$f_{ctf} = \frac{3PL}{4bd^2}$$

f_{ctf} **:** Flexural strength, Mpa

P : Maximum applied load indicated by testing machine, N
L: Span length, mm
b : Width of specimen, mm
d : Depth of specimen, mm

Relationship Between Compressive and Tensile Strength of Concrete

Tensile strength of concrete is proportional to the **square-root of the compressive strength.**

The proportionality constant depends on many factors, such as **the concrete strength** and **the test method used to determine the tensile strength.**

The following relations can be used as a rule :

$$\text{Direct tensile strength}: f_{ct} = 0.35\sqrt{f_c} \quad (f_c \text{ in MPa})$$

$$\text{Split tensile strength}: f_{cts} = 0.50\sqrt{f_c} \quad (f_c \text{ in MPa})$$

$$\text{Flexural tensile strength}: f_{ct} = 0.64\sqrt{f_c} \quad (f_c \text{ in MPa})$$

3- Shear Strength

The shear strength of concrete is taken approximately equal **to 20% its compressive strength**.

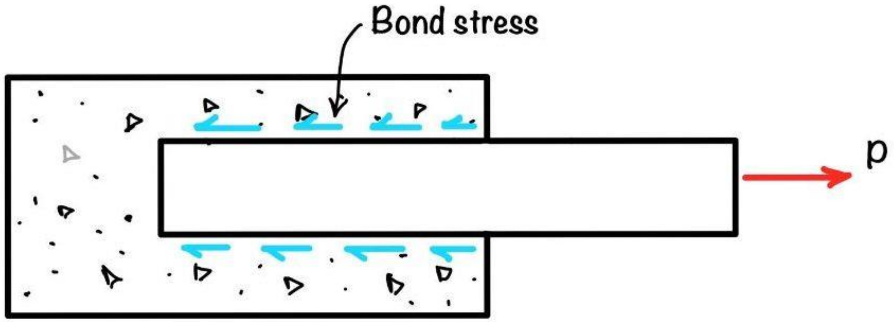
4- Bond Strength

•The strength of **bond between paste and steel reinforcement and between paste and aggregate** is called as bond strength of concrete.

•Bond strength develops primarily due to friction and adhesion between steel reinforcement and concrete.

•The bond strength of concrete is function of the compression strength and is approx. proportional to a compressive strength up to 20 MPa.

• Bond strength is also function of specific surface of gel, Cement which consist of higher percentage of C2S will give higher bond strength. On other hand, concrete containing more C3S (or concrete curved at high temperature) results in smaller specific surface of gel which gives lower bond strength.



5- Impact Strength

•Impact strength of concrete is of importance in driving concrete piles, in foundations for machines exerting impulsive loading, and also when accidental impact is possible, e.g. when handling precast concrete members

•There is no unique relation between impact strength and other concrete strengths.

•However, some researchers have found that impact is related to the compressive strength, and it has been suggested that **the impact strength varies from 0.50 to 0.75 of the compressive cube strength.**

6- Fatigue Strength

•The strength of concrete against cyclic or repeated loading is called its fatigue strength.

•The fatigue strength of concrete is much less than that of static strength due to sustained loading.

• **A fatigue limit of (50-60) % of compressive strength in static**.