Advanced Design of Reinforced Concrete

Chapter 1: Introduction, Materials and Properties

1.1 Reinforced Concrete Structures

Reinforced concrete is the union of two materials, plain concrete and steel bars.

Plain concrete - possesses high compressive strength but little tensile strength.

Steel bars - embedded in the concrete which provides the needed tensile strength.

Steel bars are also often used in compression zone of concrete to provide an added compressive strength to the beam.

1.1.1 Reasons why steel and concrete work readily:

1. Bond - prevents slip of the bars relative to concrete.
2. Proper concrete mixture - provides adequate impermeability against water and bar corrosion.
3. Similar rates of thermal expansion:
    1. Concrete - 0.000010 to 0.000013 $^\circ$C
    2. Steel - 0.000012 $^\circ$C

> Transverse cracks may appear near the steel bars in tension (unless prestressed), such cracks are expected.

1.2 Plain Concrete

Plain concrete is made by mixing cement, fine aggregates, coarse aggregate, water and sometimes, admixtures.

The strength of concrete depends on many factors:

- proportion of the ingredients
- conditions of temperature
- moisture under which it is placed and cured

1.3 Cement

Cement is a material that has adhesive and cohesive properties. These enables mineral fragments to bond and form a solid mass.

1.3.1 Portland cement

- usual hydraulic cement used in reinforced concrete. Concrete used with this attains adequate strength at **14 days** so that forms can be removed and reaches its design strength at **28 days**.

Table 1.3.1 Types of Portland Cement

Type	Uses
I	Ordinary construction, special properties are not desired
II	Ordinary construction, moderate sulfate resistance or moderate heat of hydration is desired
III	When high early strength is desired
IV	When low heat of hydration is desired
V	When high sulfate resistance is desired

1.4 Aggregates

Occupies about 75% of the total volume of concrete.

1.4.1 Normal Weight Concrete

Normal stone aggregates makes the concrete weighs about $2,300kgs/m^3$. Adding of steel reinforcement, unit weight of concrete for the purpose of calculation is $2,400kgs/m^3$.

1.4.2 Lightweight Structural Concrete

Lightweight concrete have aggregates made of expanded clays and shales and weighs about $1,120$ to $1,840kgs/m^3$

1.5 Admixtures

1.5.1 Air Entraining Admixtures

Causes air in the form of bubble (about 1mm ϕ) to form throughout the concrete to increase workability and resistance to deterioration.

1.5.2 Accelerating Admixtures

Accelerate the rate of early age strength development.

1.5.3 Water-reducing and Set-controlling Admixtures

Improve the fresh and hardening of concrete. This reduces the water cement ratio while decreasing the use of cement and increasing strength.

1.5.4 Admixture for Flowing Concrete

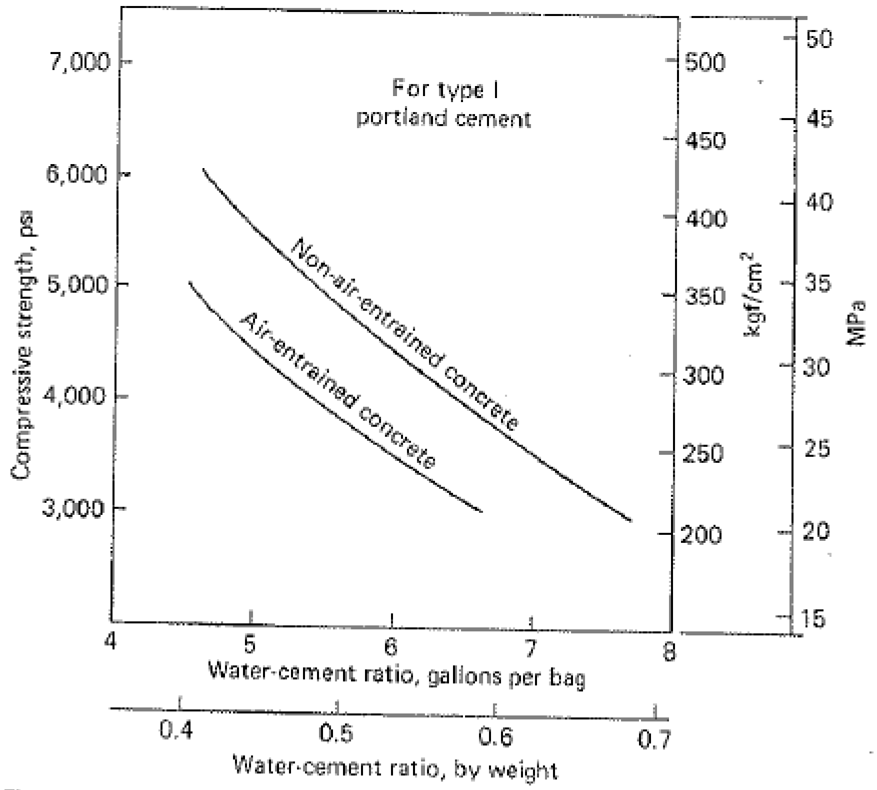
Used in concrete with high volume placement such as slabs, mats and pavements.

1.6 Compressive Strength

The strength of concrete is dependent on the mixture of cement, aggregates, water and sometimes admixtures.

Reference Concrete Strength - uniaxial compressive strength measured from cylinder compression tests.

The most important variable in determining concrete strength is the water-cement ratio. The lower the ratio, the higher the compressive strength.



Nearly all reinforced concrete behavior is related to the 28-days compressive strength, $f'c$. Note that this still depends on the size and shape of the test specimen. In normal weight concrete, in average, the 6 x 12in cylinder is 80% of the 150-mm cube strength and 83% of the 200-mm cube strength.

1.7 Tensile Strength

Tensile strength property of concrete greatly affects the size and extent of cracks in structures.

Test in this property is usually done using split-cylinder test by placing the cylinder on its side then applying the load. The split-cylinder test result has been found to be proportional to $\sqrt{f'c}$:

Modulus of rupture, $fct = 0.5\sqrt{f'c}$ to $0.6\sqrt{f'c}$ (for normal weight concrete) in MPa

Note that test result for modulus of rupture and the one calculated from $fr = \dfrac{Mc}{I}$ are different. The computed gives higher values due to compressive strength distribution is not linear when tensile failure is imminent.

1.8 Modulus of Elasticity

Modulus of elasticity of concrete varies with strength, unlike that of steel. For normal weight concrete, ACI-8.5.1 suggests

$$Ec = 5,700\sqrt{f'c}$$

where Ec is in psi, and roughly

$$Ec = 4,700\sqrt{f'c}$$

where Ec is in MPa (ACI 318-05M).

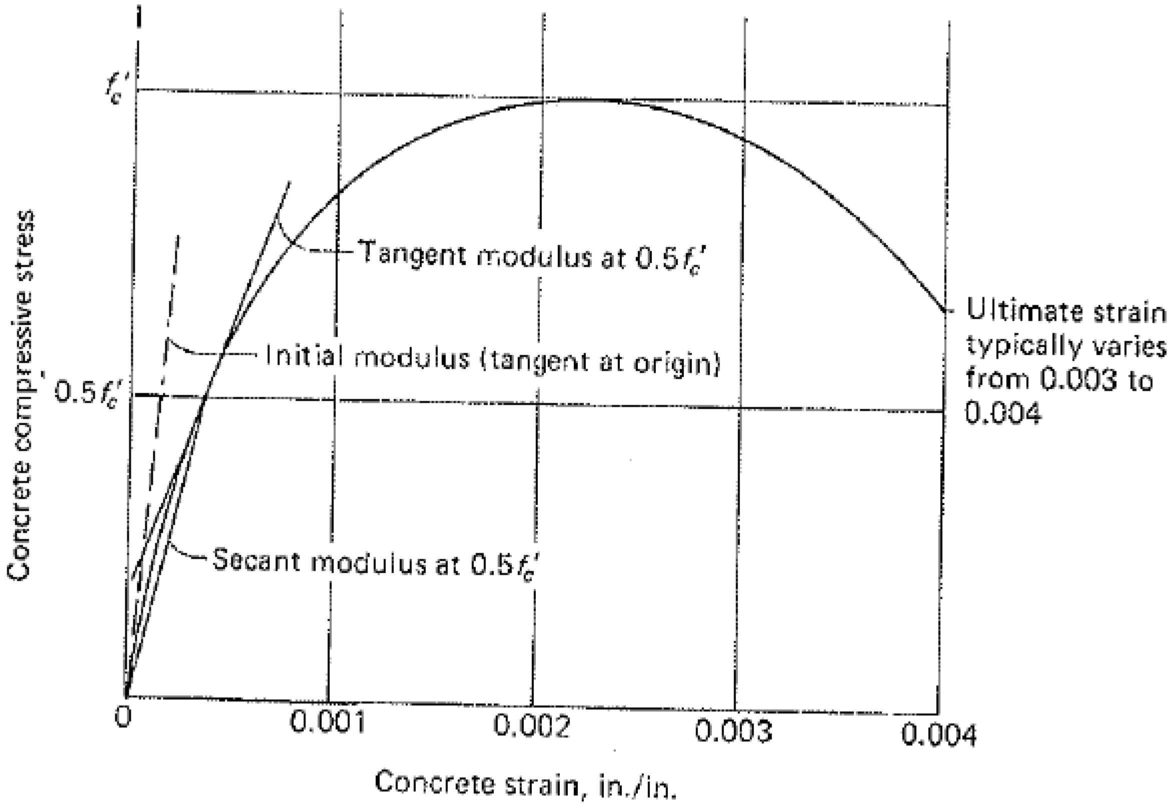


Figure 1.9.1 Stress–strain curve for concrete in compression.

1.9 Creep and Shrinkage

Properties of concrete that are hard to predict and is time-dependent. These becomes hard to predict because of inaccuracies and lots of unknown variables.

1.9.1 Creep

Creep is the property by which a material continues to deform with time under sustained loading. Factors affecting creep are composition of cement, admixture and sizes of aggregates, water-cement ratio, closing of internal voids and flow of water out of cement during drying.

1.9.2 Shrinkage

Volume change of concrete during hardening and curing. This may be controlled by continuously wetting or watering the structure during curing period.

Chapter 2: Design Methods and Requirements

2.1 Design Code

Varies depending on country. These codes must be adopted by a governing body to be legal.