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Reinforced Concrete Design

Fifth Edition

CHAPTER

1a


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MATERIALS AND MECHANICS OF BENDING

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Part I – Concrete Design and Analysis

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UNIVERSITY OF MARYLAND
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CHAPTER 1a. MATERIALS AND MECHANICS OF BENDING

Slide No. 1


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CHAPTER 1a. MATERIALS AND MECHANICS OF BENDING

Concrete

- Concrete is a mixture of cement, fine and coarse aggregates, and water.
- Water is the key ingredient for chemical reaction for curing.

Add Water



↓

Cement + Aggregates = Concrete



Concrete

■ Concrete Ingredients



Concrete

■ Cement

- Cement is a material that has the adhesive and cohesive properties necessary to bond inert aggregates into a solid mass of adequate strength and durability.



■ Aggregates

- The bulk of the concrete mix consists of the fine and coarse aggregates.



Concrete

■ Concrete Strength

- The resulting concrete *strength* and *durability* are a function of the proportions of the mix as well as other factors, such as the the concrete placing, finishing, and curing history.
- Compressive strength of concrete is relatively *high*.
- However, its tensile strength is *small* as compared with its compressive strength.



Concrete

■ Concrete Strength (cont'd)

- Hence, steel reinforcing rods, which have high tensile strength and compressive strength, are used in combination with concrete.
- The **steel** will resist the tension.
- While the **concrete** will resist the compression.





Concrete

- Concrete Strength (cont'd)
– Reinforced Concrete Beam

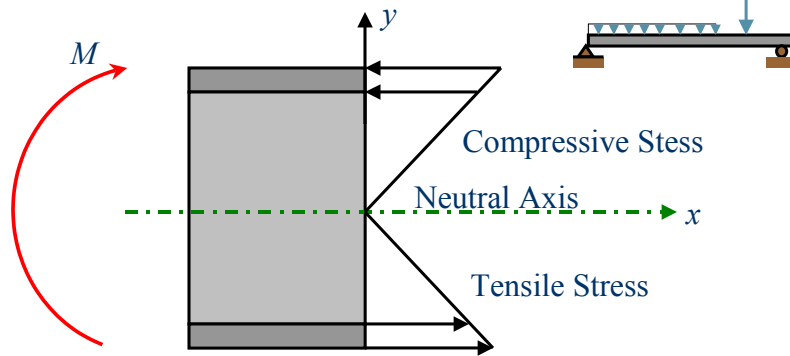


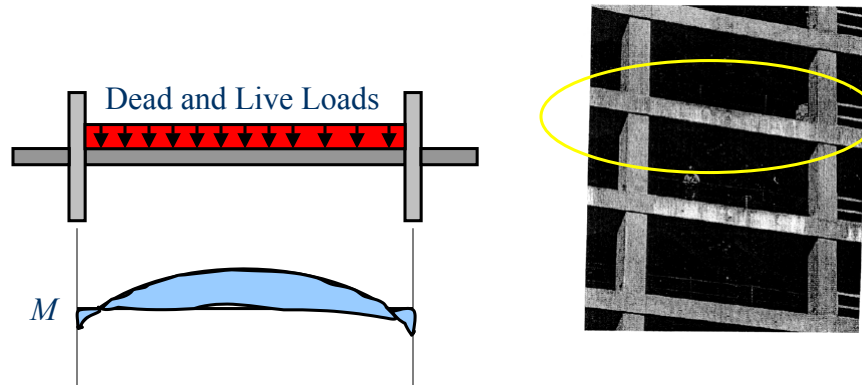
Figure 1



Concrete

- Concrete Strength (cont'd)
– Reinforced Concrete Beam

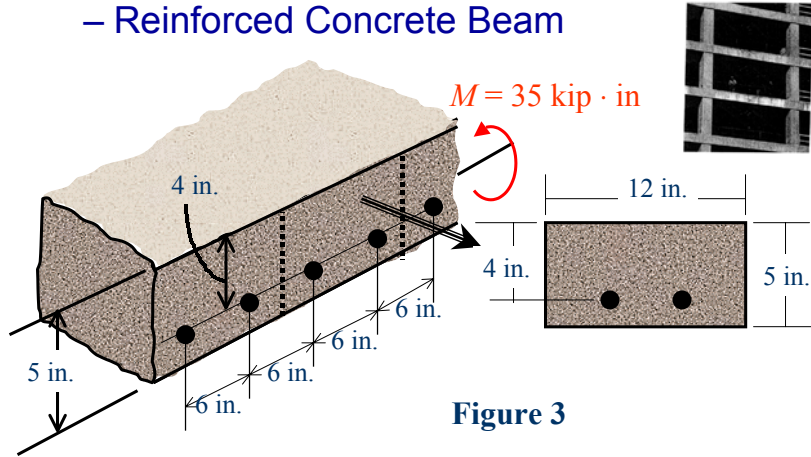
Figure 2





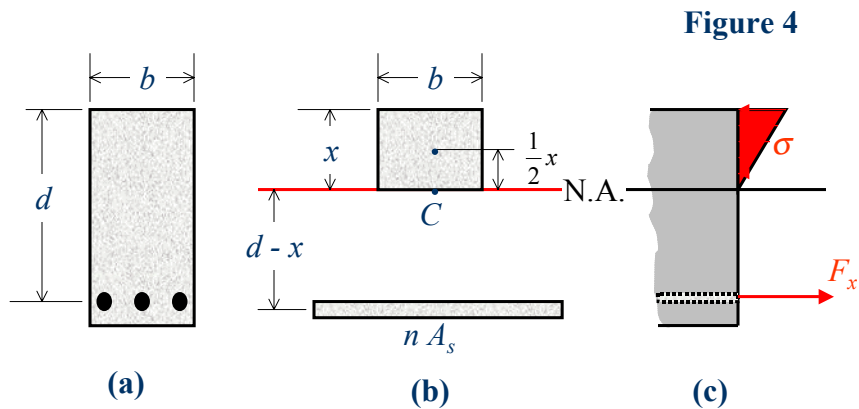
Concrete

■ Concrete Strength (cont'd) – Reinforced Concrete Beam



Concrete

■ Concrete Strength (cont'd) – Reinforced Concrete Beam





Concrete

- Concrete Strength (cont'd)
 - Reinforced Concrete Beam

– Concrete is very weak in tension, so it will crack below the neutral surface and the steel rods will carry the entire tensile load.

– The upper part of the concrete beam will carry the compressive load.



The ACI Building Code

- ACI = American Concrete Institute
 - The design and construction of concrete buildings is controlled by



“ Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (318R-02)”

- The code itself has no legal status, however, it has been incorporated into the building code of almost all states.
- When incorporated, it has official sanction.



Cement and Water

■ Hydraulic Cement:

- Water is added to hydraulic cement for the chemical reaction of hydration to take place.
- In the process of hydration, the cement sets and bonds the fresh concrete into one mass.

– **Portland Cement**

Calcium and Aluminum Silicates

Limestone materials provide Calcium Dioxide, CaO

Clays provides Silicon dioxide, SiO_2 , and Aluminum Oxide, Al_2O_3



Cement and Water

- Cement is marketed in bulk or in 94-lb (1-ft³) bags



■ Water Cement Ratio:

- The ratio of the amount of water to the amount of cement by weight



Cement and Water

- The ratio can be expressed in terms of gallons of water per bag of cement.
- Requirements
 - ***For complete hydration of cement in a mix, a water/cement ratio of***
 - *0.35 to 0.40, or*
 - *4 to 4.5 gal.bag*
 - is required.***



Aggregates

- Aggregates occupy approximately 70% to 75% of the volume of the hardened mass.
- The more densely the aggregate can be packed, the better are the *strength* and *durability*.
- Types of Aggregates:
 - **Fine:** sand (pass No. 4 sieve)
 - **Coarse:** particles (retained in No. 4 Sieve)



Concrete in Compression

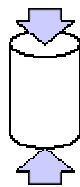
- As was mentioned earlier, compressive strength of concrete is relatively *high*.
- The compressive strength of concrete is denoted by f'_c .
- Units commonly used for f'_c :
 - Pounds per square inch (psi)
 - Kips per square inch (ksi)



Concrete in Compression

- Compression Tests and Stress-Strain Diagram

Compression



Ave. Axial Stress

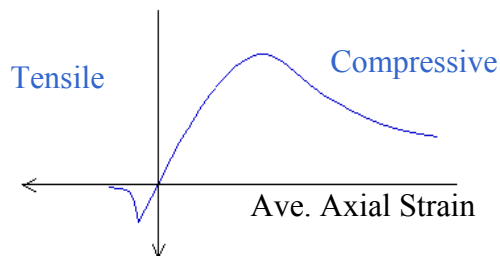
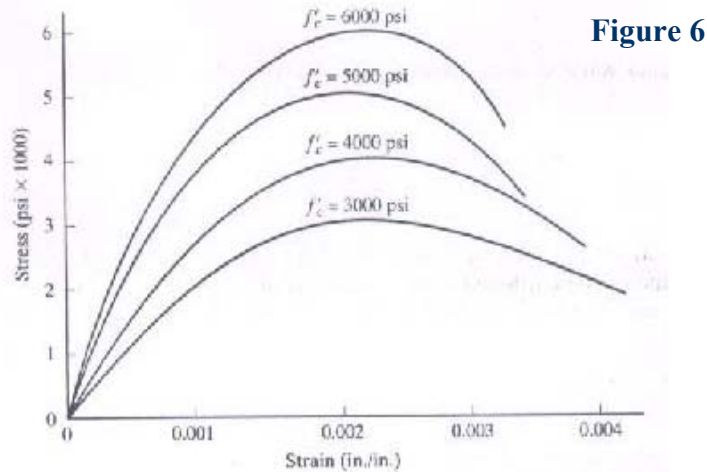


Figure 5



Concrete in Compression

■ Concrete Compressive Strength



Concrete in Compression

■ Concrete Compressive Strength

- The curves of Fig. 6 represent the result of compression tests on 28-day standard cylinders for varying design mix.
- f'_c is not the stress that exists in the specimen at failure but rather which occurs at a strain of 0.002 in/in.
- 28-day concrete strength f'_c range from 2500 to 9000 psi, with 3000 to 4000 psi being common for reinforced structures, and 5000 to 6000 psi for pre-stressed concrete members.



Concrete in Compression

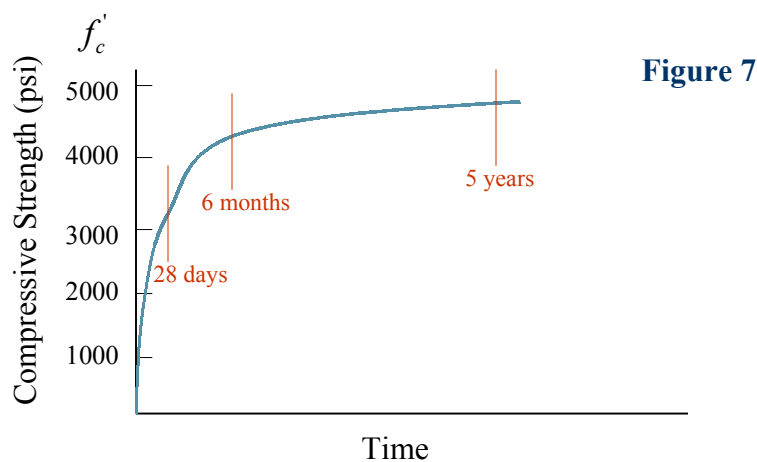
■ Concrete Compressive Strength

- Concrete strength varies with time, and the specified concrete strength is usually that strength that occurs **28 days after the placing of concrete**.
- A typical strength-time curve for normal stone concrete is shown in Fig. 7.
- Generally, concrete attains approximately 70% of its 28-day strength in 7 days, and approximately 85% to 90% in 14 days.



Concrete in Compression

■ Concrete Compressive Strength





Concrete in Compression

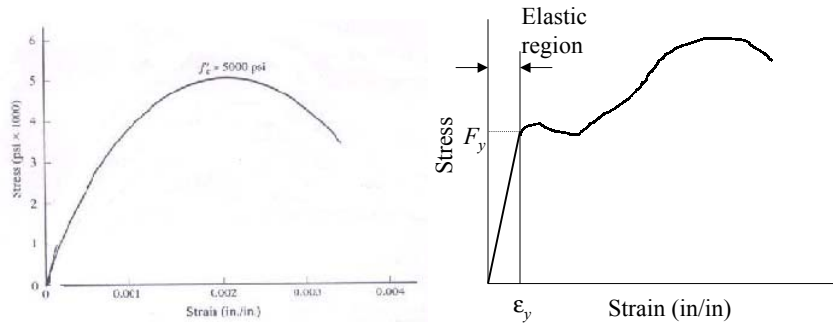
■ Modulus of Elasticity

- In review of Fig. 8a, the initial slope of the curve varies, unlike that of steel (Fig 8b), and only approximates a straight line.
- For steel, where stresses are below the yield point and the material behaves elastically, the stress-strain plot will be a straight line.
- The slope of the straight line for steel is the modulus of elasticity.



Concrete in Compression

■ Modulus of Elasticity



(a) Concrete

(b) Steel

Figure 8



Concrete in Compression

■ Modulus of Elasticity

- For concrete, however, the straight-line portion of the curve is very short, if it exists at all.
- Therefore, there exists no constant value of the modulus of elasticity for a given concrete since the stress-strain ratio is not constant.
- Even, if a straight line is assumed, the modulus of elasticity would be different for concrete of different strengths.



Concrete in Compression

■ Modulus of Elasticity

At low and moderate stresses, up to about $0.5f'_c$, concrete is commonly assumed to behave elastically.



Concrete in Compression

■ Empirical Expressions for the Modulus of Elasticity (by ACI Code)

For a unit weight w_c of concrete between 90 and 155 lb/ft³:

$$E_c = w_c^{1.5} 33\sqrt{f'_c} \quad (1)$$

where

E_c = modulus of elasticity of concrete in compression (psi)

w_c = unit weight of concrete (lb/ft³)

f'_c = compressive strength of concrete (psi)



Concrete in Compression

■ Empirical Expressions for the Modulus of Elasticity (by ACI Code)

For a unit weight w_c taken as 144 lb/ft³:

$$E_c = 57,000\sqrt{f'_c} \quad (2)$$

where

E_c = modulus of elasticity of concrete in compression (psi)

w_c = unit weight of concrete (lb/ft³)

f'_c = compressive strength of concrete (psi)



Concrete in Compression

■ Example 1

What the modulus of elasticity E_c for concrete having a unit weight of 150 pcf and a compressive strength of 5 ksi?

Using Eq. 1,

$$\begin{aligned} E_c &= w_c^{1.5} 33 \sqrt{f'_c} \\ &= (150)^{1.5} (33) \sqrt{5000} = \underline{4,286,826 \text{ psi}} \end{aligned}$$



Concrete in Compression

■ Creep

- Concrete under load, exhibits a phenomenon called *creep*.
- This a property by which concrete continues to deform over long periods of time while under a constant load.
- Creep occurs at a decreasing rate over a period of time and may cease after several years.
- Higher strength concrete exhibits less creep.