11/17/2010

→ Intro to PreStressed Concrete

Prestressed Concrete
Forces
History
Advantages
Pretensioning
Post tensioning
Losses

HW #10 Due
Mon Nov 29th

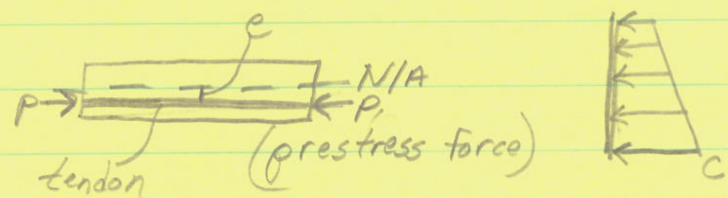
Prestress = a stress that acts even though no dead or live load is acting

Examples
  Wooden Barrels
  Early Wagon Wheels

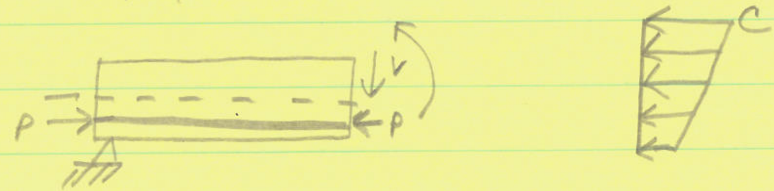
→ Forces

Service Loads

Prestress
w/eccentricity



Combined



→ Historical Background

1885-1890 ; C.F.W. Doehring - Germany
  P.H. Jackson - U.S.

1896 J. Mandl - Germany
  ↳ Theory

1907 - M. Koenen - Germany
  ↳ losses from elastic shortening

1908 - G.R. Steiner - U.S.
  ↳ Shrinkage Losses

1928 R.E.D. 11 - U.S.
↳ Prestressed Planks & fence Posts
1935 Cirruclar prestressing of Storage tanks
1949-1950 - Walnut Lane Bridge Philadelphia
↳ 1st major use of linear prestressing in U.S.

TEST * → Advantages
① Crack free under service loads
↳ reduces corrosion
↳ greater stiffness
② High Strength concrete more efficiently utilized
③ Curved tendons provide a vertical component to aid in carrying Shear

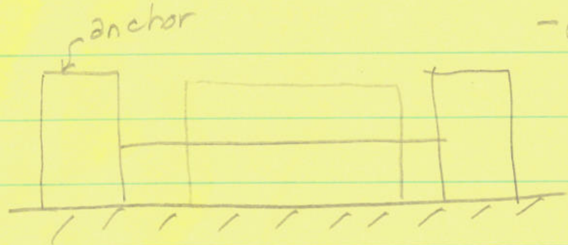
drape tendons adds shear capability

④ High ability to absorb energy (ie impact resistance)
⑤ High fatigue resistance
⑥ High Live Load capacity

Test * → Disadvantages
① Stronger Materials have higher costs
② More complicated formwork often required
③ End anchorages & bearings plates often required.
④ Labor cost are greater
⑤ More conditions to check in design

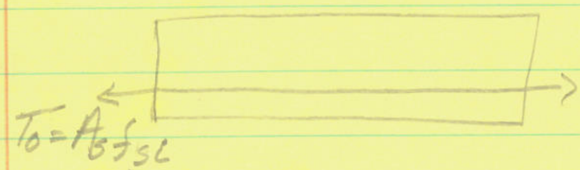
⑥ Closer control of construction required

→ Pretensioning



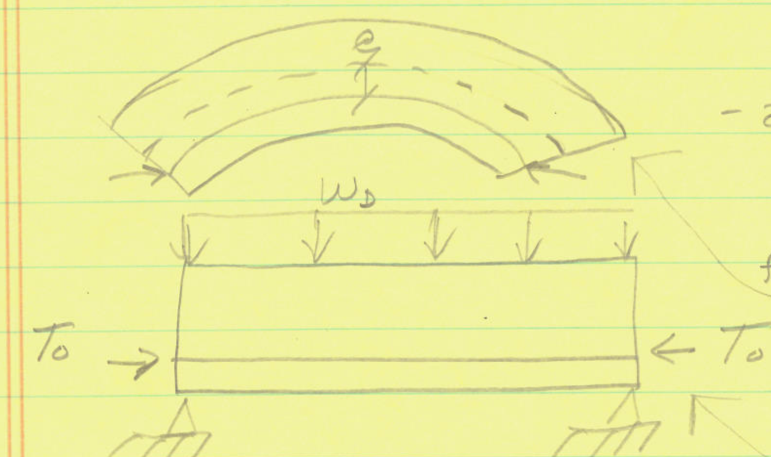
- wire stretched to f_{si} & then concrete placed around it

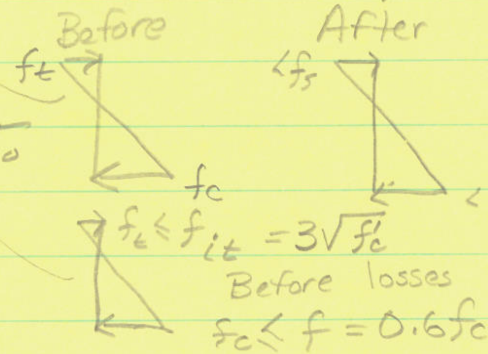
$$f_{si} \le \min \begin{cases} 94\% \, f_{py} \\ 80\% \, f_{pu} \\ \text{max value by manufacturer} \end{cases}$$



- before cutting wires/tendons there is no stress in concrete

- cut when f'_{ci} is reached (usually 4-4.5 ksi)
- after cutting wires, concrete is compressed

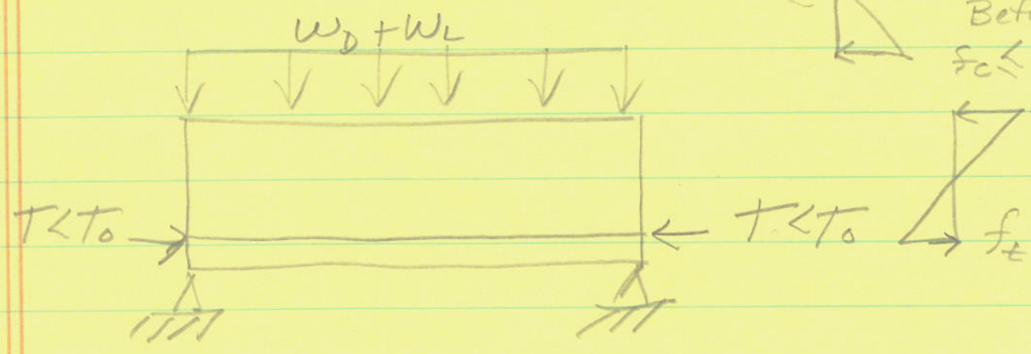




$f_t \le f_{it} = 3\sqrt{f'_c}$

Before losses

$f_c \le f = 0.6 f_{ci}$



$f_c \le f_{tc} = 0.45 f'_c$

after all losses

$f_t \le f_{ft} = 6\sqrt{f'_c}$

→ Post tension

- duct cast or unstressed tendons coated to prevent Bond
- jacking force ≤ 70% f_{pu} (70% of tendon)

→ Loss of Prestress

1. Elastic shortening of concrete due to compressio
2. Creep of concrete
3. Shrinkage in concrete
4. Relaxation of Steel Stress
5. Friction Loss

Post tension is Prestress

→ Review of Limit States — Nov 22

Strength — factored loads

Flexure $= \phi M_n \geq M_u$

Shear $\phi V_n \geq V_u$

Axial $\phi P_n \geq P_u$

Fatigue → service loads

Serviceability
Limit States
Cracking
Crack Control
Deflections
I
UnCracked I
Cracked I

→ Serviceability

Cracking
Deflection
Vibration
} based on service loads

→ Cracking

Occurs when $f_t > f_r$

f_t = tensile stress in concrete

f_r = Modulus of rupture (flexural tensile strength of concrete)

$$f_t = \frac{M y_t}{I}$$

Assumptions : Elastic
Homogeneous
Prismatic
PSRP (Plain Sections Remain Plain)

→ ACI 9.5.2.3 (cracking)

$$M_{cr} = \frac{f_r I_g}{y_t} \quad [9\text{-}9]$$ gross moment of inertia

$f_r = 7.5\sqrt{f_c'}$ ← Normal weight Concrete

$= 7.5 \dfrac{f_{ct}}{6.7}$; $\dfrac{f_{ct}}{6.7} < \sqrt{f_c'}$ Lightweight Concrete

I_g = gross moment of inertia

If $M > M_{cr}$, beam cracks

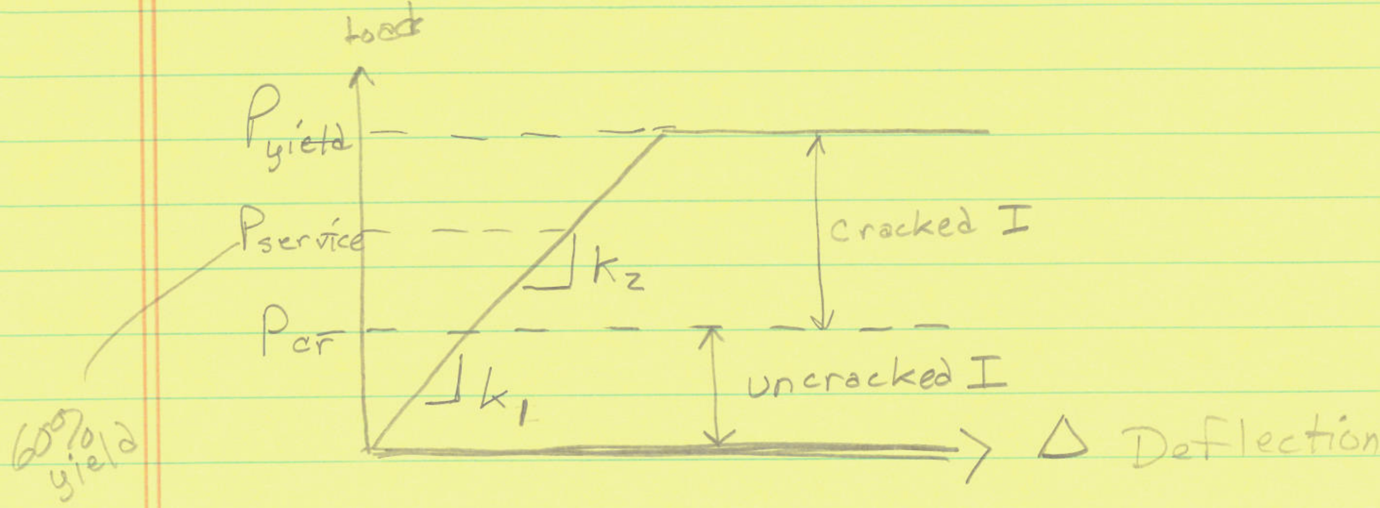
→ Crack control

- goal is to control the crack width
  - appearance
  - corrosion
  - leakage
- Controlled by
  - amount of steel
  - distribution of steel [10.6.4]

    (based on f_s @ service loads

stress the steel @ 60% unfactered loads

→ Cracking & Deflections

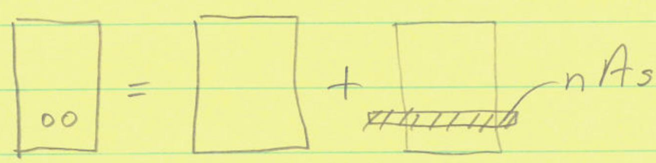


$K_1 \Rightarrow f(\text{uncracked } I) \Rightarrow EI$

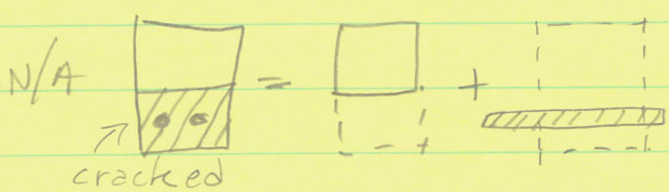
$K_2 \Rightarrow f(\text{cracked } I)$

→ Cracking & I

Uncracked Section

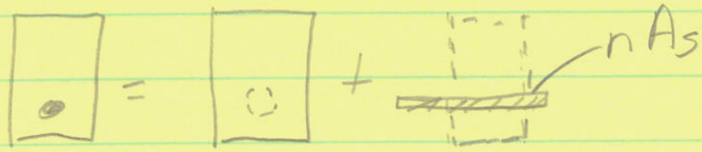


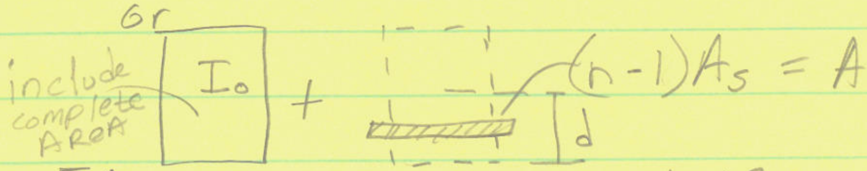
Cracked Section



$n \equiv$ modulus ratio $= \dfrac{E_s}{E_c}$

Uncracked I; $I_{uncracked}$



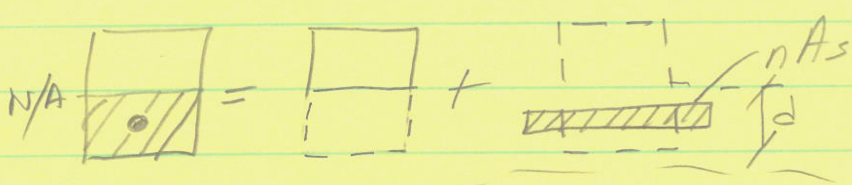


$\bar{y} = \frac{\Sigma A}{\Sigma}$. $I_{uncrack} = I_o + Ad^2$

but for most Δ deflections calculations

$I_{uncr} \approx I_g$ [9.5.2.3]

→ Cracked I, I_{cr}

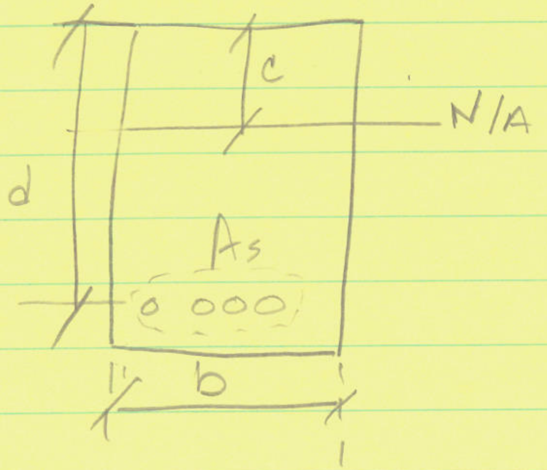


$\bar{y} = \frac{\Sigma yA}{\Sigma A}$ $\quad I_{cr} = I_o + Ad^2$ about N/A

For a rectangular beam

$$I_{cr} = \frac{bc^3}{3} + nA_s(d-c)^2$$

→ Calculating "c" in I_{cr}



calculate C by taking moments about N/A

$$n = \frac{E_s}{E_c}$$

$$\underbrace{c \cdot b}_{\text{Area}} \cdot \underbrace{\frac{c}{2}}_{\text{Arm}} = \underbrace{nA_s}_{\text{Area}} \underbrace{(d-c)}_{\text{arm}}$$

$$\frac{c^2 b}{2} = nA_s d - nA_s c$$

$$\frac{b}{2}c^2 + nA_s c - nA_s d = 0 \quad \text{solve quadratic}$$

→ Calculations of Immediate deflecting

- use service loads only
- calculate if 9.5(a) is violated
- which I value to use
- If $M_{service} \leq M_{cr} \Rightarrow I = I_{cr} \cong I_g$
- If $M_{service} \leq M_{cr} \Rightarrow I = I_E$

  $I_E \equiv$ efective moment of inertia

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– Calculation of I_E

$$I_E = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^2\right] I_{cr} < I_g$$

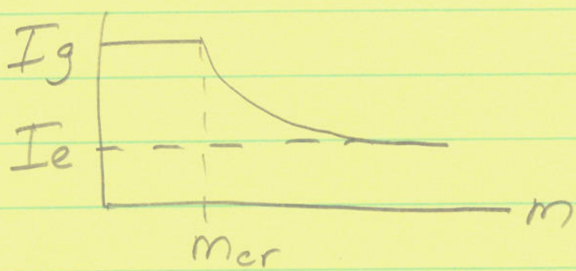
"Branson Eq"

$$M_{cr} = \frac{f_r I_g}{y_t} \quad [9\text{-}9]$$

M_a = max moment in member @ when under service loads

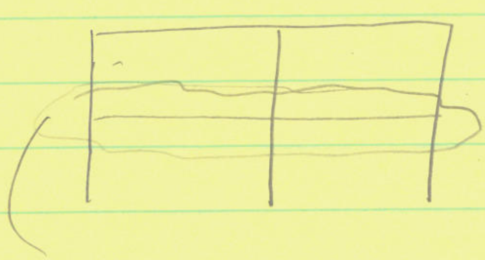
I_g = gross moment of inertia

I_{cr} = cracked moment of inertia

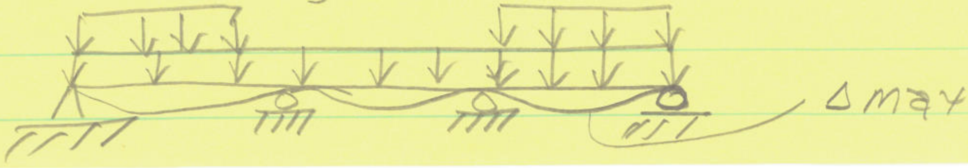


→ Calculation of deflection

· Actual Structure



can check using computer or can approximate conservetivity with



ACI on Deflections
Limits - Table 9.5(b)
Long Term Deflections

- due to creep & Shrinkage
  see [9.5.2.5] & Fig: R 2.5.2.5]

Next Slab on Grade