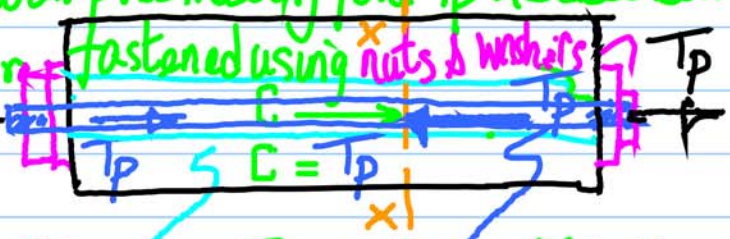
PRESTRESSED CONCRETE STRUCTURES

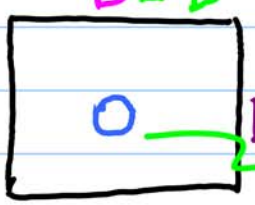
Note Title 04-01-2017

Fundamentals of Prestressed Concrete

- Basic Concepts of Prestressed Concrete (PSC) :- Definition of PSC
  - Concrete in which self-equilibrating internal stresses (compressive in Concrete and tensile stresses in prestressing steel) are generated, as a result of which the external tensile load required to crack the Concrete increases, provided the self-equilibrating stresses have predefined value
  - Prestressing of Concrete is most commonly achieved or implemented by tensioning steel against Concrete

Elementary PSC Structural Element :- Prestressed Concrete Bar - Prismatic PSC Bar with square cross section - with prestressing force T_p in steel bar cast with a Hollow Duct





Tension or Compression Element - Concentric Steel Bar of Area A_s Steel Bar with threaded ends passed thru Ducts

o Basic Concept of Prestressed Concrete :- Mechanism of Prestressing

- A PSC Bar prestressed to a Prestressing force T_p by tensioning the steel bar against Concrete to force T_p and fastening the bar (anchoring the bar) at the ends using anchors for e.g. nuts and bolts and washers assembly
  - As a result, self-equilibrating internal Compressive stress $\sigma_{cp} = \frac{T_p}{A_c}$ in concrete and internal tensile stress $\sigma_t = \frac{T_p}{2A_s}$

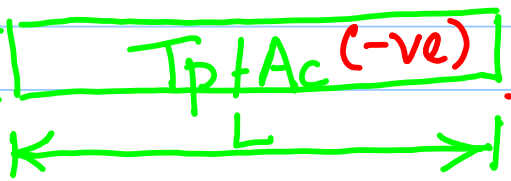
, where $A_c = b \cdot D$ and A_s = area of steel bar = $\frac{\pi D_s^2}{4}$.

assuming that the steel area $A_s << A_c$

⇒ Most Elementary Example of a PSC Structural Element is the PSC Bar prestressed by applying a uniaxial tensile force T_p

oo Definition :- Bar is a structural element that is subjected to only uniaxial tensile or Compressive force, thus inducing only axial stresse $\sigma_{cp} = \frac{T_p}{A_c}$

σ_c = stress prior to the application of the external load termed as "prestress" in concrete



+ Ve tensile
- Ve Compressive
Pre-Compressive stress or Prestress

Fundamentals of Prestressed Concrete Structures

o Basic Concepts of Prestressed Concrete (PSC)

oo Need for PSC: in the presence of Reinforced Concrete (RC) — is based on the material properties i.e.

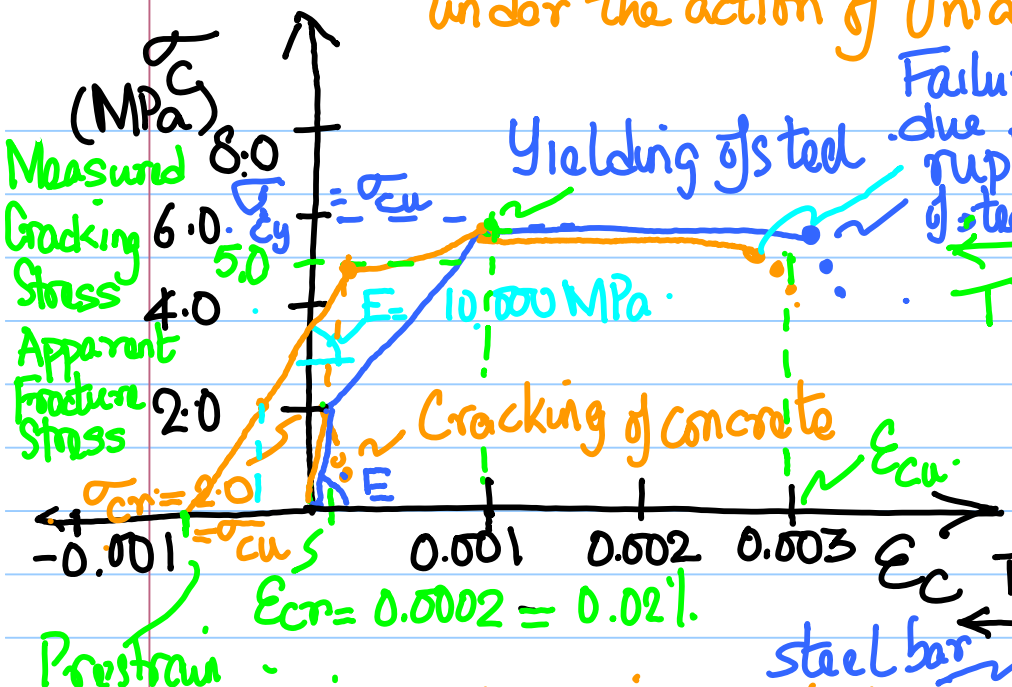
(i) Concrete is a material that extremely weak in tension with a tensile strength (cracking stress) σ_{cr} that is a small fraction of the characteristic compressive strength of concrete σ_{ck} i.e. $\sigma_{cr} = 0.05\,\sigma_{ck}$ ($\because \sigma_{cr} = 5\%$ to 10% of f_{ck} or σ_{ck})

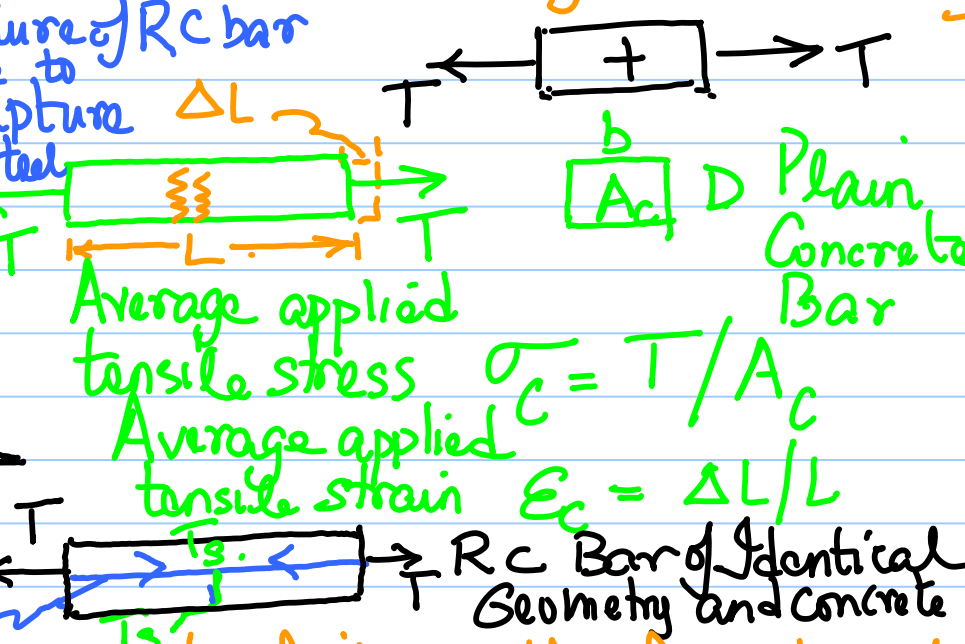
(ii) Apart from being low, the tensile strength or cracking strength σ_{cr} is also highly variable and probabilistic (random) and is associated with extremely low cracking strain ε_{cr} prior to cracking of concrete $\Rightarrow$ Concrete needs to be combined with steel in the tensile zone for concrete to be a structurally viable material

Idea of Reinforced Concrete — to combine or reinforce concrete with steel in the regions where tensile stresses can be predicted

RC is oldest composite construction after wood and brick masonry

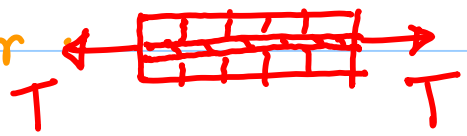
Uniaxial Stress-Strain Behavior of Plain Concrete vs. RC [with M35 grade concrete] under the action of Uniaxial Tensile Force.





In case of plain concrete bar, Concrete fails on the formation of first crack (plain concrete cannot resist or transmit any tensile force upon/after cracking) $\Longrightarrow$ Ultimate stress or Ultimate strength in case of plain concrete at failure $\sigma_{cu} = \sigma_{cr}$ ✓

Corresponding Ultimate Strain $\varepsilon_{cu} = \varepsilon_{cr}$



BASIC CONCEPTS OF PRESTRESSED CONCRETE STRUCTURES

Need for Prestressed Concrete (PSC) in presence of Reinforced Concrete (RC)

o Uniaxial Tensile Stress-Strain Behavior of Plain Concrete vs. RC vs. PSC

Property or Parameter	Plain Concrete Bar composed of M35 grade Concrete		Reinforced Concrete Bar of identical geometry and grade with 1.5% of HYSD steel R/F (Bar)	Prestressed Concrete Bar of identical geometry & grade with 0.25% of Prestressing Steel
1. Cracking Stress σ_{cr} (MPa).	2.0	=	2.0 (Fe 415 steel) (2.5 times RC)	<< 5.0
2. Cracking Strain ε_{cr}	0.0002 (0.02%)	=	0.0002 .	= 0.0002 (∵ Material Property of Concrete)
3. Elastic Modulus E_c (MPa) $= \sigma_{cr}/\varepsilon_{cr}$	10,000		10,000	<< 25,000
4. Ultimate tensile Stress or Strength (MPa) (f_{cu})	2.0	<<	6.0 (3 times of Plain Concrete)	= 6.0 (dictated by failure of steel)
5 Ultimate tensile Strain (ε_{cu})	0.0002	<<<	0.003 (15 times that of Plain Concrete)	= 0.003

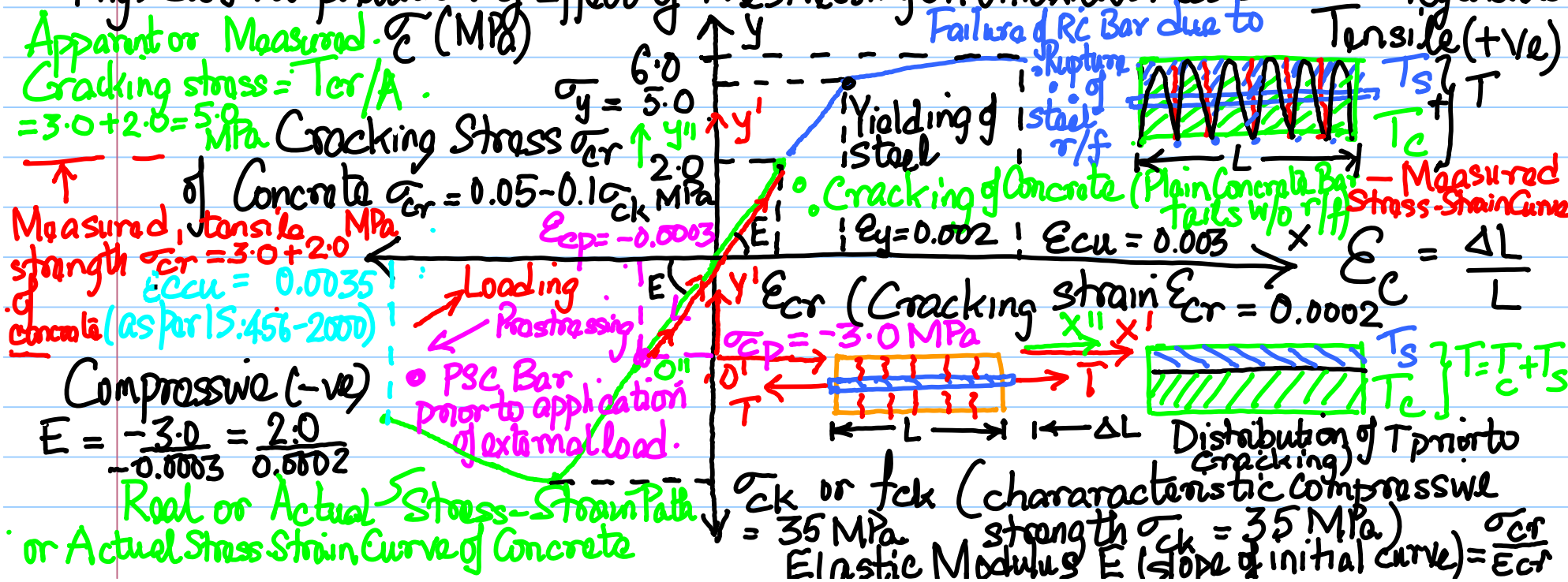
Note :- In contrast, a RC bar does not fail upon the formation of first crack but continues to resist axial tension by transmitting Tensile force thru the steel bar across the cracks until steel ruptures.

Fundamentals of Prestressed Concrete

- Idea of Prestressed Concrete (PSC) :- Basic Idea or the Working Principle of PSC can be conveniently illustrated by interpretation of the effect of prestressing on the uniaxial stress-strain behavior of Concrete as a material and compare and contrast the effect of simple reinforcing with steel reinforcement (i.e reinforcing steel without any prestressing or passive steel r/f) in physical terms.

Note :- Choice of transformed coordinates x'y' assumes that the strain gage is installed prior to prestressing

- Physical Interpretation of Effect of Prestressing on Uniaxial Stress-Strain Curve of Concrete.



FUNDAMENTALS OF PRESTRESSED CONCRETE

Need for Prestressed Concrete (PSC).

- Comparison of Uniaxial Tensile Stress-Strain Behavior of PSC vs. RC
  - Interpretations of the Uniaxial Stress-Strain Curves – (a) The prestressing steel in case of PSC compresses the concrete to a desired or pre-defined compressive strain termed as "prestrain" (in this $\varepsilon_{cp} = -0.0003$) prior to the application of the external tensile load (when $T = 0$). On the application of the external tensile force ($T > 0$), as T increases from zero, concrete has to be first relieved from the pre-compressive stress termed as "prestress" before concrete enters the tensile range of stress or strain.
  - (b) As a result, the external tensile force T_{cr} or corresponding externally applied average tensile stress $\sigma_{cr} = T_{cr}/A$ that is required to crack the concrete in case of PSC is 2.5 times that for RC (with reference to x'y')

Conclusions:- Prestressing enhances the measured cracking stress or cracking strength of concrete (σ_{cr}). However, the ultimate tensile stress σ_{cu} and strain ε_{cu} remain more or less the same for PSC as those for RC at the ultimate limit state $\Rightarrow$ Prestressing enhances the pre-cracking or elastic performance of concrete only.

BASIC CONCEPTS OF PRESTRESSED CONCRETE

Idea of Prestressed Concrete

To apply a pre-compressive stress to a material (for e.g. concrete) that is weak and brittle in tension but relatively strong and ductile in compression using prestressing steel so that the cracking strength or fracture strength or tensile strength of the material is enhanced. It should that prestressing increases only the measured or "apparent" tensile strength

- Practical importance of the Idea of PSC – By selecting an appropriate value of the prestrain or corresponding initial compressive stress i.e. prestress $\sigma_{cp} = \varepsilon_{cp} \cdot E_c$, the PSC elements can be designed to remain uncracked, in principle, in the working range of loads (service loads). In contrast, RC elements cannot be designed to remain uncracked under working loads (service loads) for reasons of economy since the cost of designing RC element for uncracked section would be prohibitive or uneconomical (RC structures are designed to crack under working loads (service loads)
  - PSC structures can designed cost-effectively to remain uncracked in the working stress range by selecting value of prestrain ε_{cp} by design