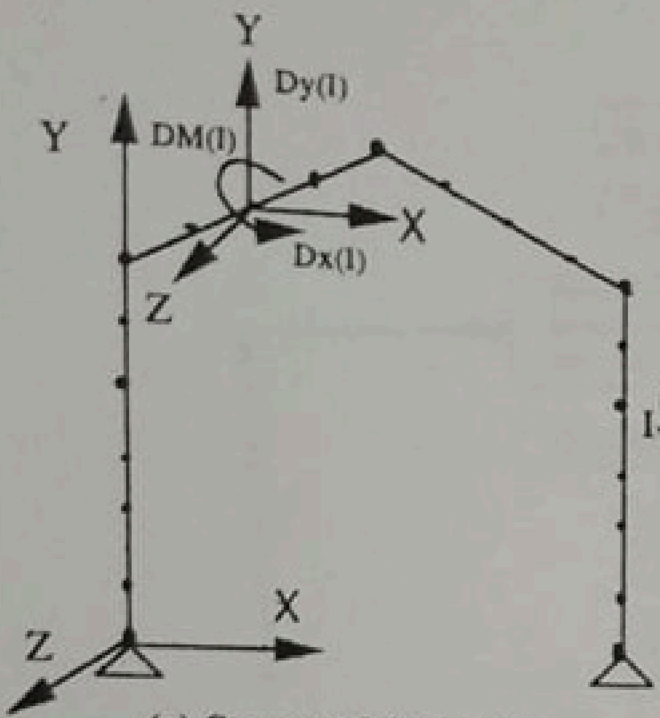
Banha University
Faculty of Engineering - Shoubra
Civil Engineering Department

Computation of Nonlinear (STR602)

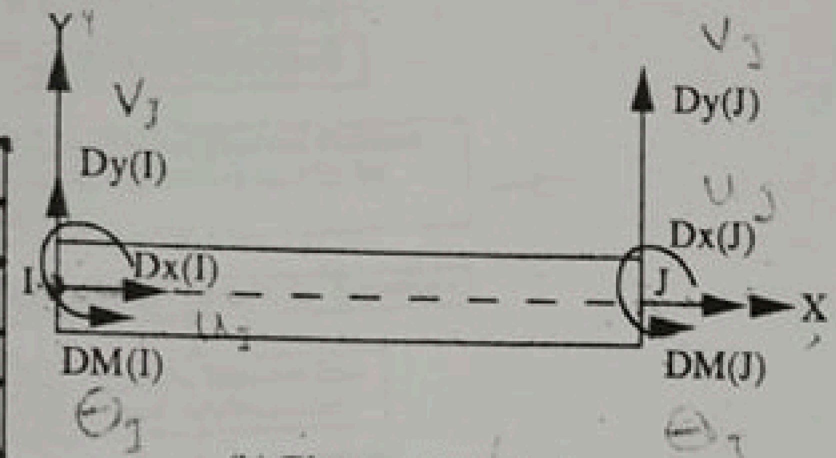
For Master of Engineering Sciences

Assoc. Prof. Taha Ibrahim

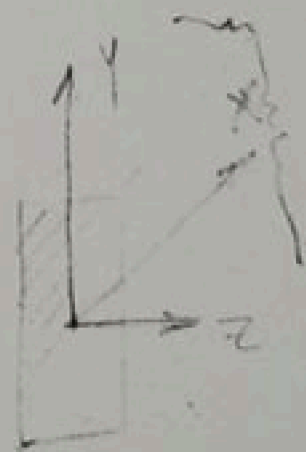
Lecture 2

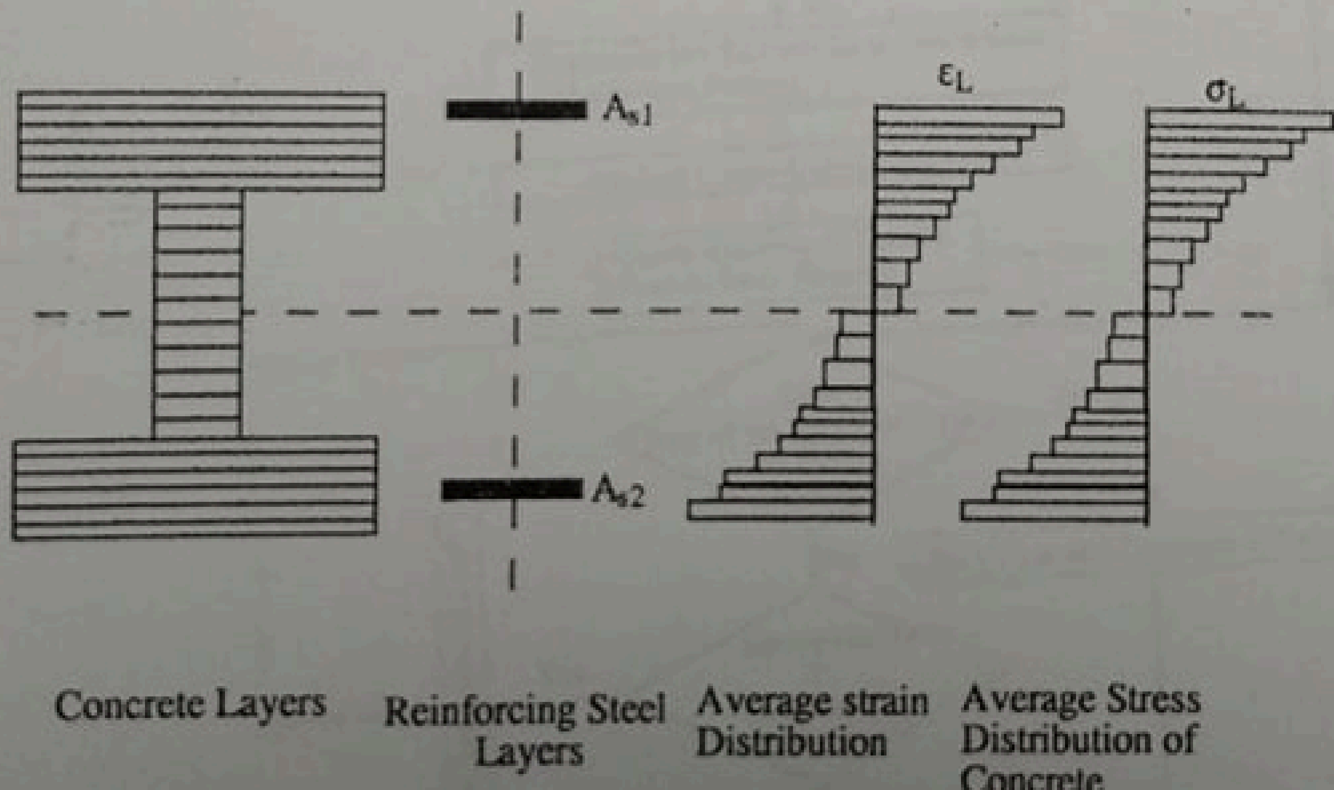


(a) Structural Geometry



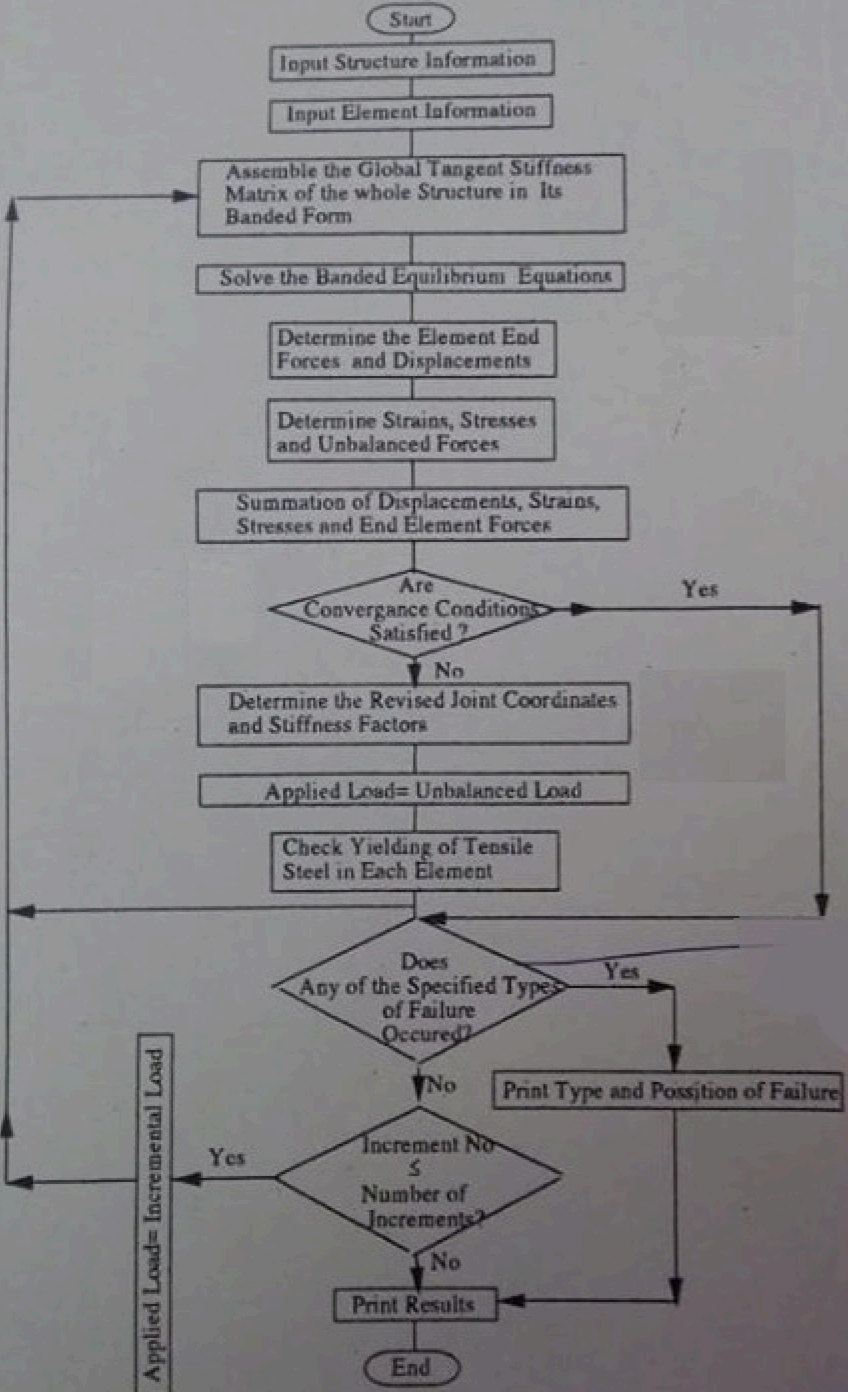
(b) Element Geometry



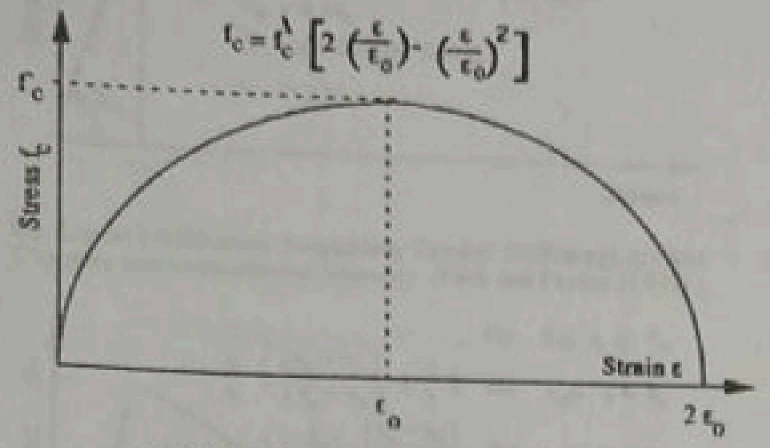


(c) Layered System

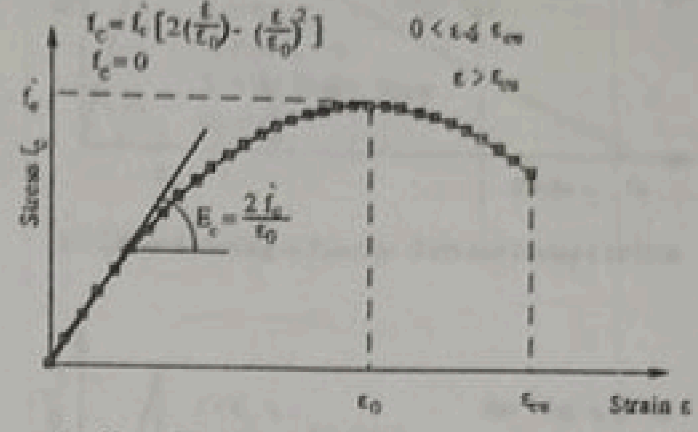
Geometrical Definations and Cross Section of Layered System



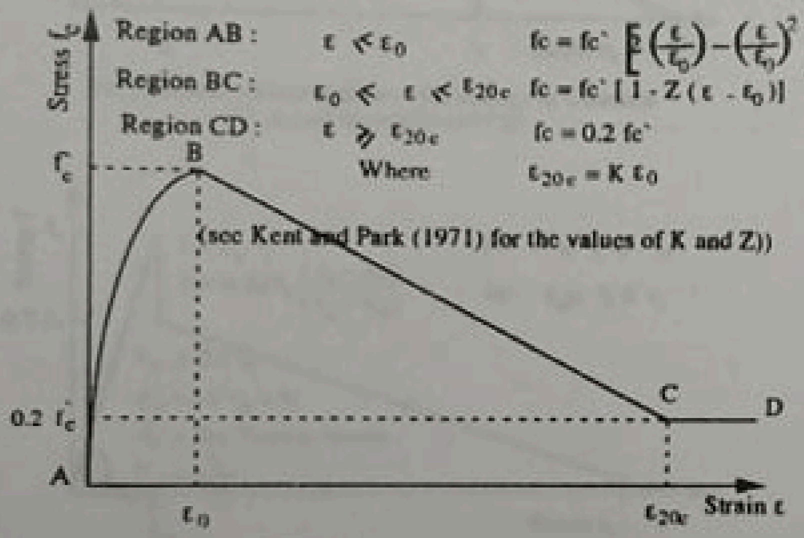
Flow Chart for the Plane Frame Program



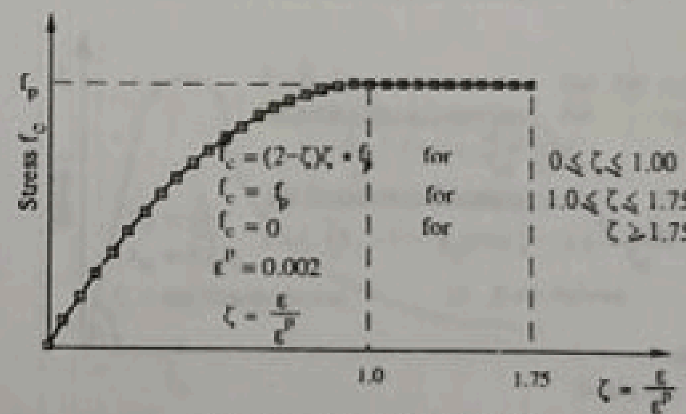
(a) Unconfined Concrete (Vecchio Model (1986))



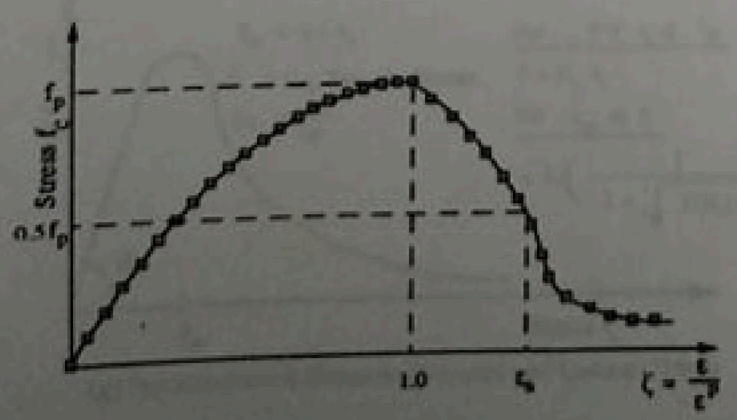
(b) Unconfined Concrete (Modified Vecchio Model (1986))



(c) Confined Concrete (Kent-Park Model (1971))



(d) "CEB" Model Code (1970)



(e) Modified "CEB" Model Code (1970)

$$f_c = f_p\left(\frac{M\cdot\zeta - \zeta^2}{1 + (M-2)\zeta}\right) \quad \text{for } \zeta \le \zeta_u$$

$$f_c = f_p \Big/ \left[\left(\frac{N}{\zeta_u} - \frac{2}{\zeta_u^2}\right)\zeta^2 + \left(\frac{4}{\zeta_u} - N\right)\zeta\right] \quad \text{for } \zeta \ge \zeta_u$$

$$\zeta = \frac{\varepsilon}{\varepsilon^p} \qquad \varepsilon^p = 0.002$$

$\zeta_u = \frac{\varepsilon_u}{\varepsilon^p}$ where ε_u is the post peak strain at stress $0.5\, f_p$

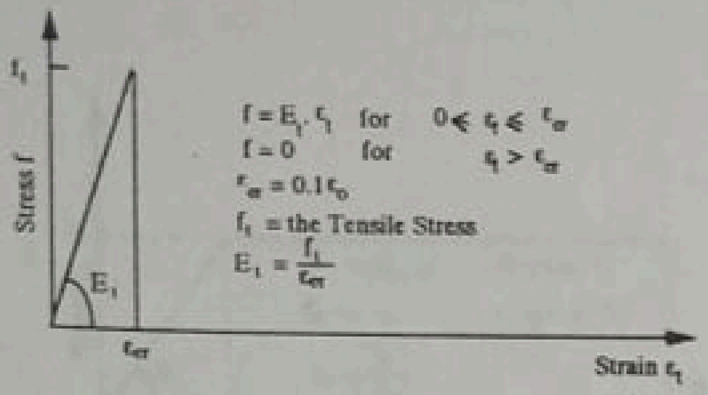
$M = \frac{E^0}{E^p}$ where $E^p = \frac{f_p}{\varepsilon^p}$ (f_p in Kips / in^2)

f_p(in MPa) $= \frac{f_p \text{(in Kips / in}^2\text{)}}{690}$

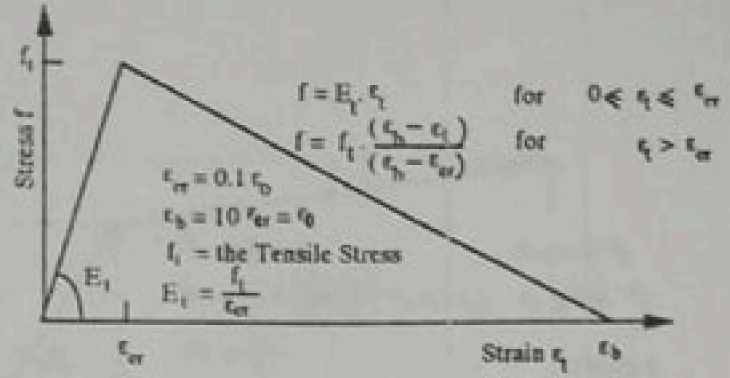
$$N = 4\left[\zeta_u^2(M-2) + 2\zeta_u - M\right] \Big/ \left[\zeta_u(M-2) + 1\right]^2$$

$E^0 = 1420\,(f_p/0.142)^{1/3}$ (f_p in Kips / in^2)

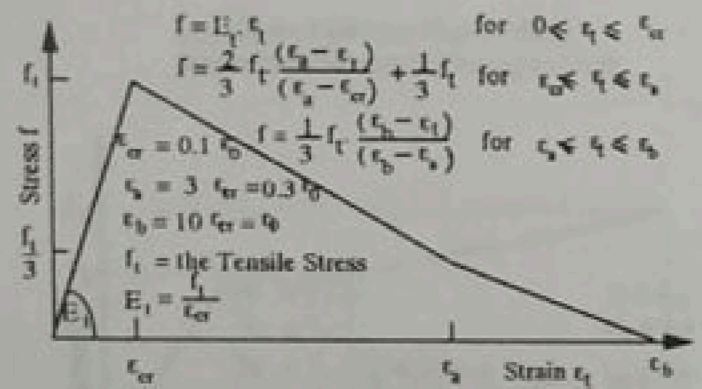
Idealized Stress-Strain Curves for Concrete in Compression



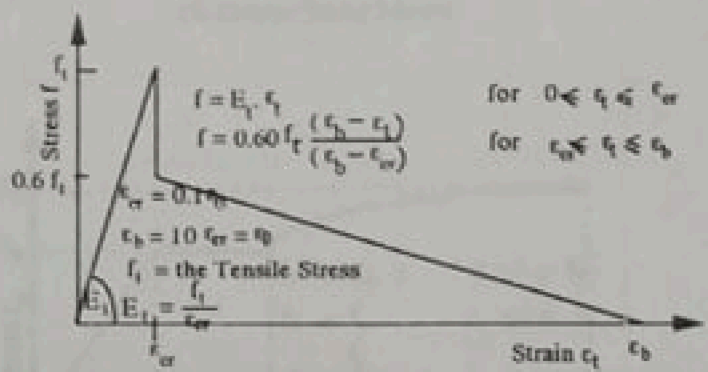
(a) Linear Idealization (Neglecting Tension Stiffening) in Plain Concrete and Unreinforced Masonry (Park and Paulay (1975))



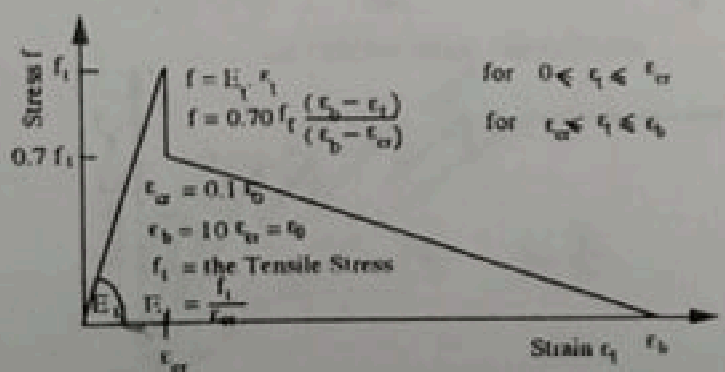
(b) Linear Softening in Concrete (Park and Paulay (1975))



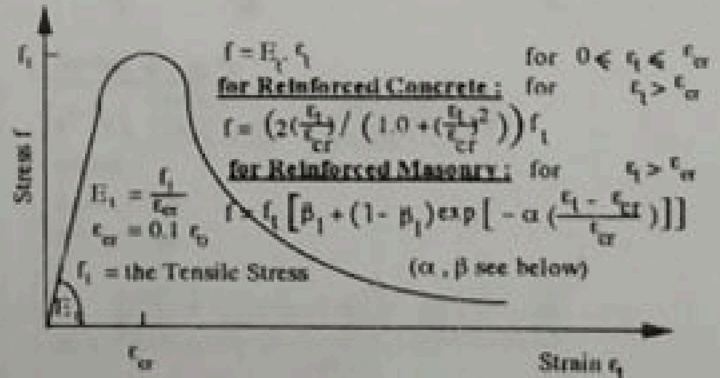
(c) Trilinear Model (Bilinear Softening) in Concrete (Lin and Scordelis (1975))



(d) Discontinuous Softening (1) in Concrete (Gilbert and Warner (1978))



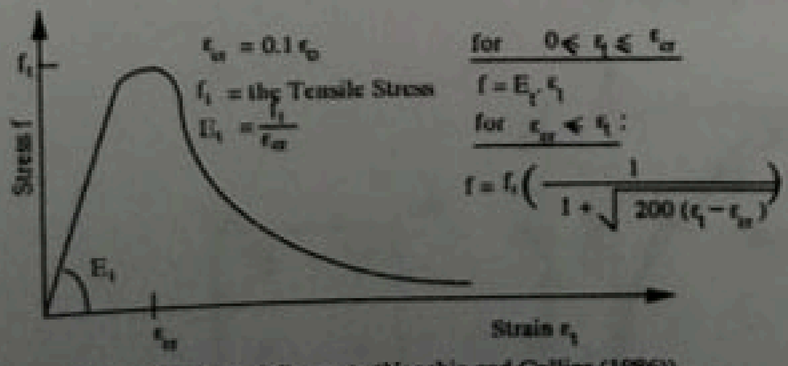
(e) Discontinuous Softening (2) in Concrete (Gilbert and Warner (1978))



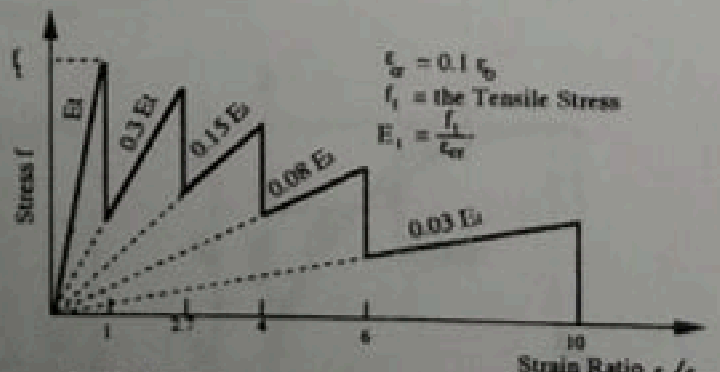
(f) Complete Curve for Reinforced Concrete (Carreia and Chu (1986))
Complete Curve for Reinforced Masonry (Gupta (1990))

- α is an exponential parameter which is related to the percentage of reinforcement υ
- β_1 is the lower limit for the exponential branch which is related to the percentage of reinforcement υ

υ	α	β_1
0.25 %	0.06	0.38
0.35 %	0.10	0.48
0.50 %	0.18	0.50
0.75 %	0.25	0.50



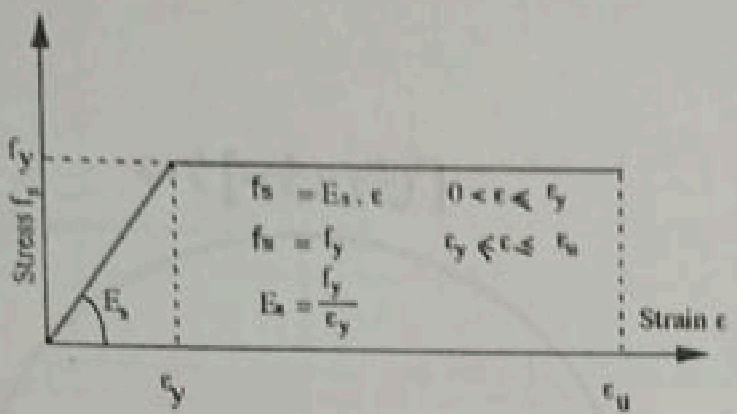
(g) For Reinforced Concrete (Vecchio and Collins (1986))



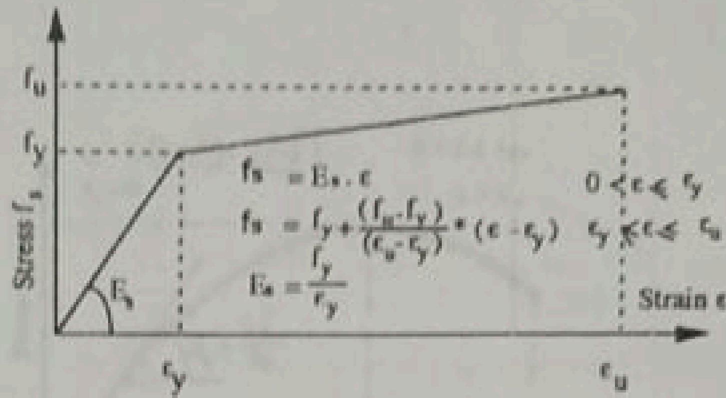
(h) Modified Stress-Strain Diagram for Concrete in Tension Considering Tension Stiffening in Concrete After Cracking (Gilbert and Waner (1978))

ε_{cr} = the tensile cracking strain
f_{cr} = the tensile cracking stress
ε_0 = the Uniaxial compressive strain
E_t = the elastic modulus in tension
ε_t = the tensile strain
f_t = the tensile stress
ε_0 = 0.002 for masonry
ε_0 = 0.003 for concrete

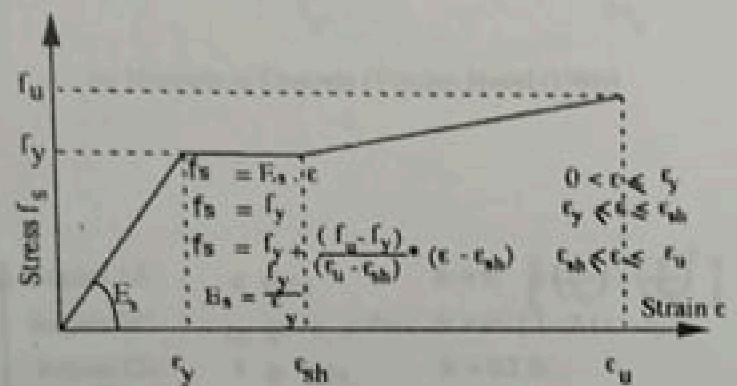
Idealized Stress-Strain Curves for Concrete and Masonry in Tension



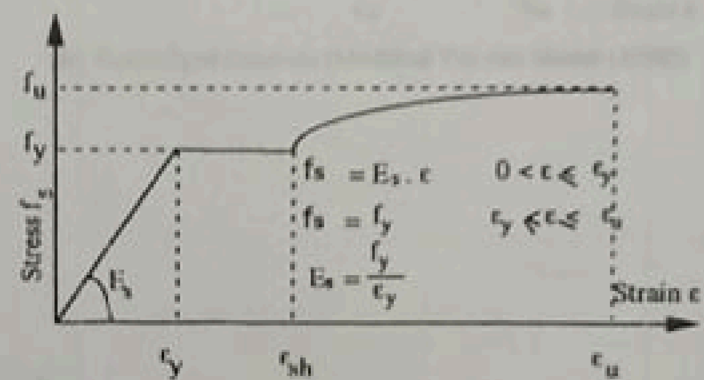
(a) Elastic Perfectly Plastic Model
Neglecting Tension Stiffening in Steel



(b) Elasto-Plastic Model



(c) Trilinear Stress - Strain Curve



for $\varepsilon_{sh} \le \varepsilon \le \varepsilon_u$

$$f_s = f_y\left(\frac{(m*k+2)}{(60*k+2)} + \frac{k(60-m)}{(2*(30r+1)^2)}\right)$$

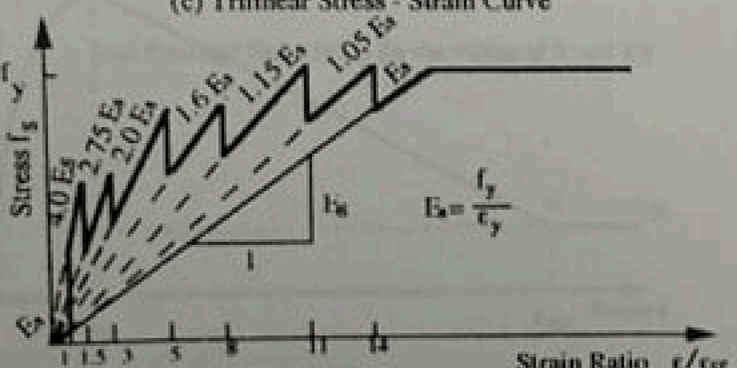
where

$k = r - \varepsilon_{sh}$

$r = \varepsilon_u - \varepsilon_{sh}$

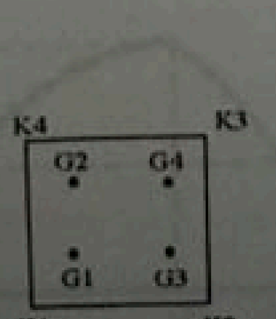
$$m = \frac{\left[\left(\left(\frac{f_u}{f_y}\right) * (30*r + 1.0)^2\right) - 60*r - 1.0\right]}{15*r^2}$$

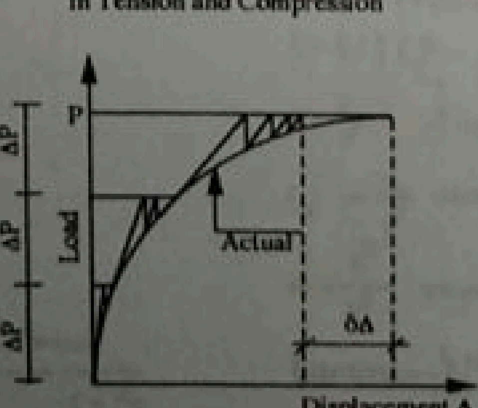
(d) Complete Curve Model



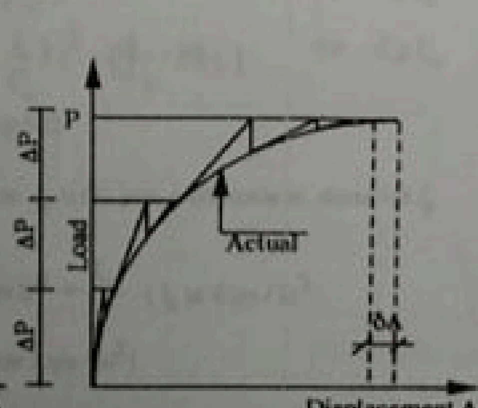
(e) Modified Stress-Strain Curve for Steel in Tension
(Considering Tension Stiffening in Concrete
After Cracking (Gilbert Model (1978)))

Fig. 4 Idealized Stress-Strain Curves for Steel Reinforcement
in Tension and Compression





(1) Constant Stiffness in Load Steps



(2) Tangent Stiffness in Load Steps

(a) Finite Element Model

(b) Incremental - Iterative Loading Methods

Finite Element Model and Loading Methods