CIE 306
CONCRETE STRUCTURES I

A- <u>Procedure for the analysis of Rectangular Singly-Reinforced Beams</u>

a. Assume tension steel yields $\Rightarrow f_s = f_y$

b. Calculate the depth of the stress block $a = \dfrac{A_s f_y}{0.85 f_c^{'} b}$

c. Determine the depth of the neutral axis $c = \dfrac{a}{\beta_1}$

d. Check the strain in the tension steel using similar triangles $\varepsilon_s = 0.003\dfrac{d-c}{c}$

i. If $\varepsilon_s \geq 0.005 \Rightarrow$ *Beam is tension controlled* $\Rightarrow f_s = f_y$ *and* $\phi = 0.9$

ii. If $0.002 \leq \varepsilon_s < 0.005 \Rightarrow$ *beam is in transition* $\Rightarrow f_s = f_y$ *and* $\phi = 0.65 + (\varepsilon_t - \varepsilon_y)\dfrac{250}{3}$

$\varepsilon_s < 0.002 \Rightarrow$ *Beam is compression controlled* $\Rightarrow \phi = 0.65$ *and* $f_s \neq f_y$

$T = C$

$\Rightarrow A_s f_s = 0.85 f_c^{'} ab \Rightarrow A_s E \varepsilon_s = 0.85 f_c^{'} \beta_1 cb \Rightarrow A_s E \times 0.003\dfrac{d-c}{c} = 0.85 f_c^{'} \beta_1 bc$

iii. If $\Rightarrow 0.85 f_c^{'} \beta_1 bc^2 + 0.003 A_s Ec - 0.003 A_s Ed = 0$

Calculate c

Calculate $\varepsilon_s = 0.003\dfrac{d-c}{c}$

Calculate $f_s = E\varepsilon_s$

e. Determine $\phi M_n = \phi A_s f_s \left(d - \dfrac{a}{2}\right)$ *where* $a = \beta_1 c$

B- <u>Procedure for the Design of Rectangular Singly-Reinforced Beams (Restricted Design)</u>

a. Calculate U = 1.2 W_{DL}+1.6 W_{LL}
b. Calculate M_u from U
c. $\varphi M_n = M_u$
d. $\phi M_n = \phi b d^2 \bar{k}$
e. Assume tension controlled beam $\Rightarrow \phi = 0.9$
f. Assume $d = h - 3$
g. Calculate $\bar{k} = \dfrac{\phi M_n}{\phi b d^2}$
h. Calculate ω *by solving* $\bar{k} = \omega f_c^{'}(1 - 0.59\omega)$
i. Calculate $\rho = \dfrac{\omega f_c^{'}}{f_y}$

j. Check $\varepsilon_s = 0.003\left(\frac{0.85 f_c^{'}\beta_1}{\rho f_y} - 1\right) \geq 0.005$

k. Calculate $A_s = \rho bd$

l. Check $A_s \geq A_{s_{\min}}$ $\quad where\ A_{s_{\min}} = \begin{cases} \frac{3\sqrt{f_c^{'}}}{f_y} b_w d \\ \frac{200}{f_y} b_w d \end{cases}$

m. Select steel from Table A-2 and check if it fits within b from Table A-3.

n. Check $d_{actual} \geq d_{assumed}$

C- <u>Procedure for the Design of Rectangular Singly-Reinforced Beams (Free Design)</u>

a. Calculate $U^{'} = 1.2\ W_{DL} + 1.6\ W_{LL}$

b. Calculate M_u from $U^{'}$

c. $\varphi M_n = M_u$

d. $\phi M_n = \phi b d^2 \bar{k}$

e. Assume $\varepsilon_s = 0.0075$

f. Calculate ρ *from the equation* $\varepsilon_s = 0.003\left(\frac{0.85 f_c^{'}\beta_1}{\rho f_y} - 1\right)$

g. Calculate $\omega = \frac{\rho f_y}{f_c^{'}}$

h. Calculate $\bar{k} = \omega f_c^{'}(1 - 0.59\omega)$

i. Assume $\frac{d}{b} = 2 \Rightarrow d = 2b \Rightarrow M_u = \phi b(2b)^2 \bar{k} \quad \Rightarrow b = \sqrt[3]{\frac{M_u}{4\phi\bar{k}}}$

j. Calculate $d = 2b\ and\ h = d + 3$

k. Determine weight of beam as $w_b = 0.15 \times \frac{bh}{144}$

l. Calculate $U = U^{'} + 1.2\ w_b$

m. Calculate new M_u from U

n. Calculate $\bar{k} = \frac{M_u}{\phi b d^2}$

o. Calculate ω *by solving* $\bar{k} = \omega f_c^{'}(1 - 0.59\omega)$

p. Calculate $\rho = \frac{\omega f_c^{'}}{f_y}$

q. Check $\varepsilon_s = 0.003\left(\frac{0.85 f_c^{'}\beta_1}{\rho f_y} - 1\right) \geq 0.005$

r. Calculate $A_s = \rho bd$

s. Check $A_s \geq A_{s_{\min}}$ *where* $A_{s_{\min}} = \begin{cases} \dfrac{3\sqrt{f_c^{'}}}{f_y} b_w d \\ \dfrac{200}{f_y} b_w d \end{cases}$

t. Select steel from Table A-2 and check if it fits within b from Table A-3.