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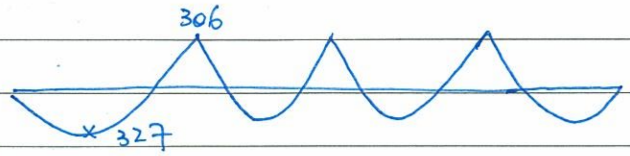
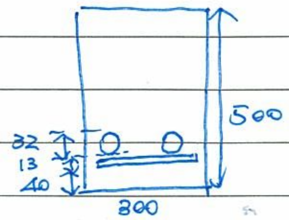
CV3011 S1 2015 - 2016

Date No.

1a) after 0.85 distribution





$360 \times 0.85 = 306$

$360 - 306 = \cancel{60}\,54$

$54/2 = 27$

$300 + 27 = 327$

height of beam = 500mm. concretecover: 40mm, stirrup size: 13mm

assume diameter of steel bars 32 mm.

$d = 500 - 40 - 13 - 32/2 = 431$ mm

$K = M/bd^2 f_{ck} = (327 \times 10^6)/(300)(431)^2 40 = 0.147 < 0.167$ $\delta = 1$

$\therefore$ singly reinforced, compression steel is not needed.

$z = d\left(0.5 + \sqrt{0.25 - \frac{K}{1.134}}\right) = 0.847d = 365\text{mm} < 0.95d$

$A_s = M/0.87 f_{yk} z = 327 \times 10^6/(0.87 \times 500 \times 365) = 2059.5\ \text{mm}^2$

provide 3H32 $A_s = 2414\ \text{mm}^2$

b) $K = M/bd^2 f_{ck} = 306 \times 10^6/(300)(431)^2(40) = 0.137 > K_{bal} = 0.129$

$\therefore$ compression steel is needed

$d' = 40 + 13 + 32/2 = 69$ mm

$d'/d = 69/431 = 0.16 > 0.125$

$\therefore$ compression steel has not yielded.

$\varepsilon_{sc} = 0.0035(x - d')/x$ $x_{bal} = 0.328(431) = 141.4$

$= 0.00179169$

$f_{sc} = E_s \cdot \varepsilon_{sc} = 200 \times 10^3 \times 0.00179169 = 358.34\ \text{N/mm}^2$

$$A'_{sc} = \frac{(K - K_{bal}) f_{ck} bd^2}{f_{sc}(d - d')} = \frac{(0.137 - 0.129)(40)(300)(431)^2}{358.34(431 - 69)} = 137.5$$

$$A_s = \frac{K_{bal} f_{ck} bd^2}{0.87 f_{yk} z} + A'_{sc}\left(\frac{f_{sc}}{0.87 f_{yk}}\right)$$

$z_{bal} = 0.869(431) = 374.54$

$$= \frac{0.129(40)(431)^2(300)}{0.87(500)(374.54)} + 137.5\left(\frac{358.34}{0.87 \times 500}\right)$$

$= 1765 + 113.\cancel{3}$

$= 1878\ \text{mm}^2$

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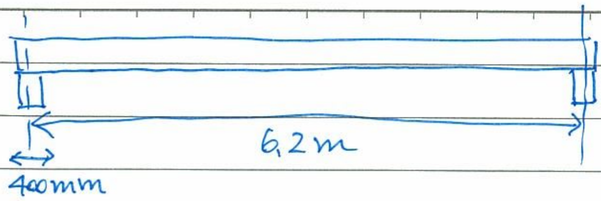
2a)



Design load $= 1.35 \times 70 + 1.5 \times 46$
$= 163.5 \text{ kN/m}$

$M_{max} = \frac{1}{8}(163.5)(6.2)^2 = 785.6 \text{ kNm}$

$g_k = 70 \text{ kN/m}$ $\quad q_k = 46 \text{ kN/m}$ $\quad h = 575$ $\quad b_w = 275$ $\quad d = 575 - 35 - 12 - 32/2$
$= 512$

$n = 1.35(70) + 1.5(46) = 163.5 \text{ kN/m}$

$V_{max} = 163.5 \times 6.2 / 2 = 506.85 \text{ kN}$ $\quad$ assume steel bar $\phi 32$

$V_{Ef} = V_{max} - n \times l_w \times 0.5$
$= 506.85 - 163.5 \times 400 \times 0.5 \times 1000^{-1}$
$= 474.15 \text{ kN}$

zone 1 $\quad V_{Rd,max(22)} = 0.124 b_w d (1 - f_{ck}/250) f_{ck}$
$= 0.124(275)(512)(1 - 40/250) 40 \cdot 10^{-3}$
$= 586.63 \text{ kN} > V_{Ef}$

Let $\theta = 22°$ and $\cot(\theta) = 2.5$

zone 2: At 1d ($d = 512$ mm) from support face

$V_{E1d} = 474.15 - 163.5 \times 0.512 = 390.438 \text{ kN}$

$\therefore \frac{A_{sw}}{S_2} = \frac{V_{E1d}}{0.78 d f_{yk}(2.5)} = \frac{390.438 \times 10^3}{0.78 \cdot 512 \cdot 500 \cdot 2.5} = 0.78$

$\therefore$ select $\phi 12$ at 275mm spacing, $A_{sw}/s = 0.822$

zone 3: $\frac{A_{s\,min}}{S} = \frac{0.08 f_{ck}^{0.5} b_w}{f_{yk}} = \frac{0.08(40)^{0.5} \times 275}{500} = 0.2783$

Select $\phi 12$ at 400mm spacing $\quad A_{sw}/S = 0.565$

Actual shear resistance of stirrup is

$V_{min} = \frac{A_{sw}}{s} 0.78 d f_{yk} \cot(\theta) = 0.565(0.78)(512)(500) \times 2.5 \times 10^{-3}$

$= 282.048 \text{ kN}$

Number of stirrup used for zone 1 & 2

$X_L = \frac{V_{Ef} - V_{min}}{\cancel{w} n} = \frac{474.15 - 282.048}{163.5} = 1.175 \text{ m}$

STATIONERY

$$\text{Number of links} = 1 + \frac{X_L}{S_2} = 1 + \frac{1.175 \times 10^3}{275} = 5.27 = 6$$

$$\text{Length} = 5 \times 275 = 1375\ mm$$

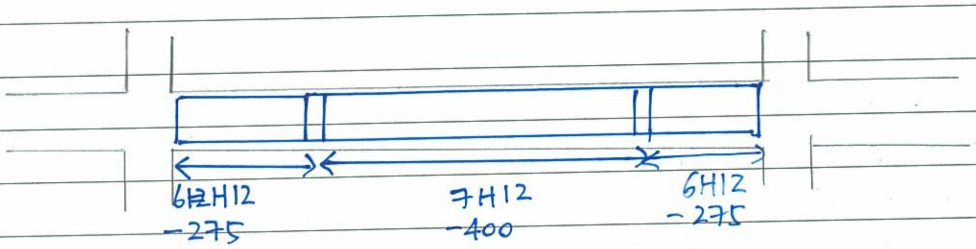
number of stirrups used for zone 3.

$$L_3 = L - 2 \times (\text{half width of support}) - 1375 \times 2$$

$$= 6200 - 2 \times (200) - 1375 \times 2$$

$$= 3050\ mm$$

$$\text{Number of links} = \frac{L_3}{S_3} - 1 = \frac{3050}{400} - 1 = 6.625 = 7.$$



a) $F1 = 1 - 0.1[bf/bw - 1] = 1 - 0.1[650/275 - 1] = 0.864$

$F2 = \frac{7}{6.2} > 1 \quad F2 = 1.0$

$K = 1$

$\psi_2 = 0.6$, $Gk/Qk = 70/46 = 1.52$, $\gamma_G = 1.35$, $\sigma_{su} = 260\ N/mm^2$

$d = 575 - 35 - 12 - 32/2 = 512mm$

$K = \frac{785.6 \times 10^6}{40 \times 650 \times 512^2} = 0.1153$ (assume neutral axis lies within flange)

$z = 0.885d = 453\ mm$

$S = 2(d - z) = 2(\cancel{45}\ 512 - 453) = 117.6\ mm < 150$ ∴ assumption was correct

$As = 785.6 \times 10^6 / ((0.87) \times 500 \times 453) = 3986.7\ mm^2$ (Asreq)

Asprov 5H32 ($4023\ mm^2$)

$p = 100(3986)/(275 \times 512) = 2.83\% > 2\% \Rightarrow l/d = 14$

$\sigma_s = 260 \times 3987/4023 = 258$ "

$F3 = 310/258 = 1.2$

allowable $L/d = 1 \times 14 \times 0.864 \times 1.0 \times 1.2 = 14.5$

Actual $L/d = 6.2(1000)/512 = 12.11 < 14.5$ (ok)

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3a) $6/5 = 1.2$ $n = (0.15 \times 25 + 1.25) \times 1.35 + 1.5 \times 4 = 12.75\ kN/m^2$

$M_x = 0.074 \times 12.75 \times 5^2 = 23.5875\ kNm$ $d_x = 120\ mm$

$M_y = 0.056 \times 12.75 \times 5^2 = 17.85\ kNm.$ $d_y = 110\ mm$

Flexure along x direction:

$$\frac{M}{bd^2 f_{ck}} = \frac{23.5875 \times 10^6}{1000(120)^2(25)} = 0.0655$$

$$z = d\left(0.5 + \sqrt{0.25 - \frac{0.0655}{1.134}}\right) = 0.9384d$$

$$As_{req} = \frac{23.5876 \times 10^6}{0.87 \times 500 \times 0.9384 \times 120} = 481.5\ mm^2/m$$

$As_{prov} = H10 - 150\ (524\ mm^2/m)$

Flexure along y direction

$$\frac{M}{bd^2 f_{ck}} = \frac{17.85 \times 10^6}{1000(110)^2 25} = 0.059$$

$$z = d\left(0.5 + \sqrt{0.25 - \frac{0.059}{1.134}}\right) = 0.945d$$

$$As_{req} = \frac{17.85 \times 10^6}{0.87 \times 500 \times 0.945 \times 110} = 394.75\ mm^2/m$$

$As_{prov} = H10 - 180\ (437\ mm^2/m)$

Deflection check (x direction)

$\rho_0 = 10^{-3}\sqrt{f_{ck}} = 10^{-3}(25)^{1/2} = 0.005$

$\rho = As_{req}/bd = 481.5/(1000)(120) = 0.0040 < \rho_0$

$K = 1$

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_0}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right]$$

$$= 1\left[11 + 1.5\sqrt{25}\,\frac{0.005}{0.004} + 3.2\sqrt{25}\left(\frac{0.005}{0.004} - 1\right)^{3/2}\right]$$

$$= 22.375$$

Allowable $L/d = 22.375 \times As_{prov}/As_{req} = 22.375 \times 524/481.5 = 24.35$

Actual $L/d_x = 5000/120 = 41.67 > 24.35$ (Not ok)

b) ① increase As_{prov}

$span/d = 41.67 = 22.375 \times MF$ $MF = 1.86 = As_{prov}/As_{req}$

$As_{prov} = 1.86 \times 481.5 = 897\ mm^2$

use $H10 - 80\ (982\ mm^2)$

② increase slab thickness to 175mm

$d_x = 145$ mm $\qquad d_y = 135$ mm

$n = (0.175 \times 25 + 1.25) \times 1.35 + 1.5 \times 4 = 13.6$ kN/m²

$M_x = 0.047 \times 13.6 \times 5^2 = 15.98$ kNm

$M_y = 0.056 \times 13.6 \times 5^2 = 19.04$ kNm

x direction :

$$\frac{M}{bd^2 f_{ck}} = \frac{15.98 \times 10^6}{1000(145)^2(25)} = 0.0304$$

$z = d\left(0.5 + \sqrt{0.25 - \frac{K}{1.134}}\right) = 0.97d$ use $z = 0.95d$

$$As_{req} = \frac{15.98 \times 10^6}{0.87 \times 500 \times 0.95 \times 145} = 266.7 \text{ mm}^2/\text{m}$$

use H10 – $\cancel{286}$ 250 $\cancel{275}$ (As_{prov} = $\cancel{286}$ 314 mm²/m)

$p = As_{req} / bd_x = 266.7 / (1000) / 145 = 0.00184 < 0.35\%$

Allowable $L/d = 30 \times As_{prov} / As_{req} = 30 \times \cancel{286}\ 314 / 266.7 = \cancel{32.25}\ 35.32$

Actual $L/d_x = 5000/145 = 34.5 < 35.32$ (OK)

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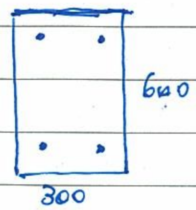
4a) 1. Pure axial compression ($M=0$)



$N_o = 0.567 f_{ck} \cdot A_{col} + 0.87 f_{yk} A_{sc}$

$= 0.567 \times 25 \cdot 300 \times 600 + 0.87(500)(300)(600)(0.02)$

$= 4117.5 \text{ KN}$ point 1 $(0, 4117.5)$

2. Balanced condition of failure : $\varepsilon_{cu} = 0.0035$, $d/h = 0.9$ $d = 540$ mm $d' = 60$

$\varepsilon_y = 0.87 \times 500 / 200000 = 0.00217$

$$X_{bal} = \frac{d}{1 + \frac{\varepsilon_y}{0.0035}} = \frac{540}{1 + \frac{0.00217}{0.0035}} = 333 \text{ mm}$$

check if the compression steel has yielded

$\varepsilon_{sc} = 0.0035\left(\frac{x-d'}{x}\right) = 0.0035\left(\frac{333-60}{333}\right) = 0.0029 > 0.0025 \rightarrow$ yield

$F_{s1} = F_{s2} = 0.87 f_{yk} \times 300 \times 600 \times 0.02 = 1566000 \text{ N}$

$F_c = 0.567 f_{ck} \times 300 \times 0.8 X_{bal} = 1132866 \text{ N}$

$N = N_{bal} = F_c + F_{s1} - F_{s2} = 1132866 \text{N} = 1132.9 \text{KN}$

$M_{bal} = F_c(300 - 0.4 X_{bal}) + (F_{s1} + F_{s2})(d - 300)$

$= 1132866(300 - 0.4(333)) + (1566000 + 1132866)(540 - 300)$

$= 836.7 \text{ kNm}$

point 2: $(836.7, 1132.9)$

3. Pure bending ($N=0$)

assume the compression steel has not yielded

$$\varepsilon_{s1} = \frac{x-60}{x} \times 0.0035$$

$$f_{s1} = \frac{x-60}{x} \times 700$$

$$0.567 \times 25 \times 300 \times 0.8x + \left(\frac{x-60}{x}\right) \times 1800 \times 700 = 0.87 \times 500 \times 1800$$

$$3402x + 1260000\left(\frac{x-60}{x}\right) = 783000$$

$$3402x^2 + 1260000x - 75600000 = 783000x$$

$$x = 774431/8184 = 94.6$$

$f_{s1} = 256.15 \Rightarrow F_{s1} = 461077$

$M = F_c(d - 0.4x) + F_{s1}(d - 60) = 382.93 \text{KN}$

point 3: $(383, 0)$

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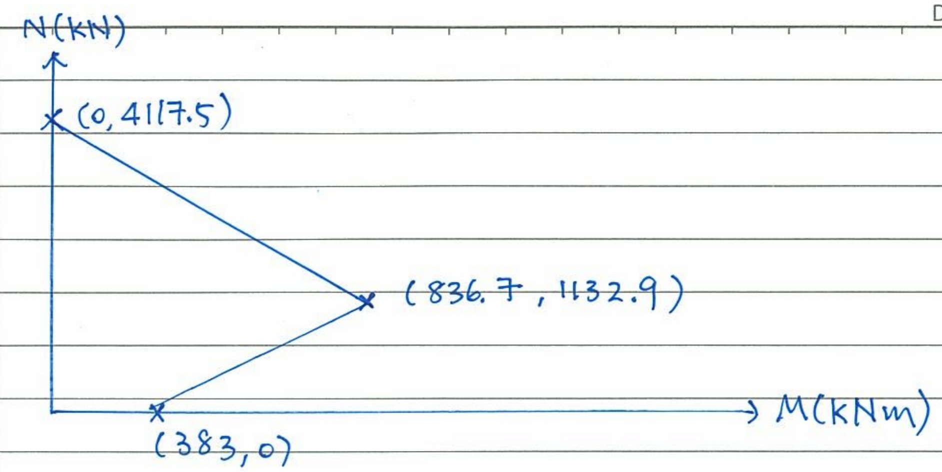
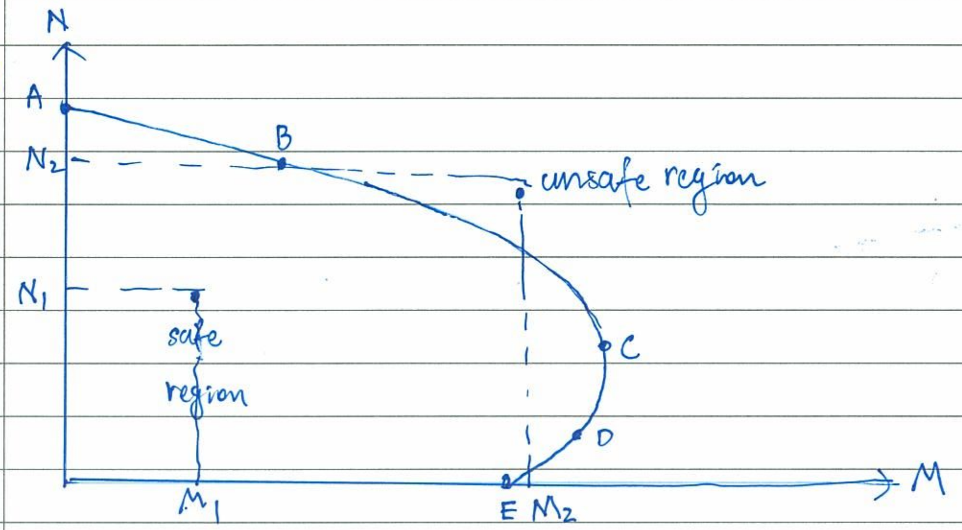


b)



A-B: all zero tension

A-C: compression controlled failure, tension steel has not yielded, compression steel has yielded

C-E: tension controlled failure, tension steel has yielded, compression steel has not.

C: balanced failure ~~m~~ crashing of concrete (0.0035) and yielding of tensile steel (0.00217) at the same time

beyond pt C, $x < x_{bal}$

E: pure bending.