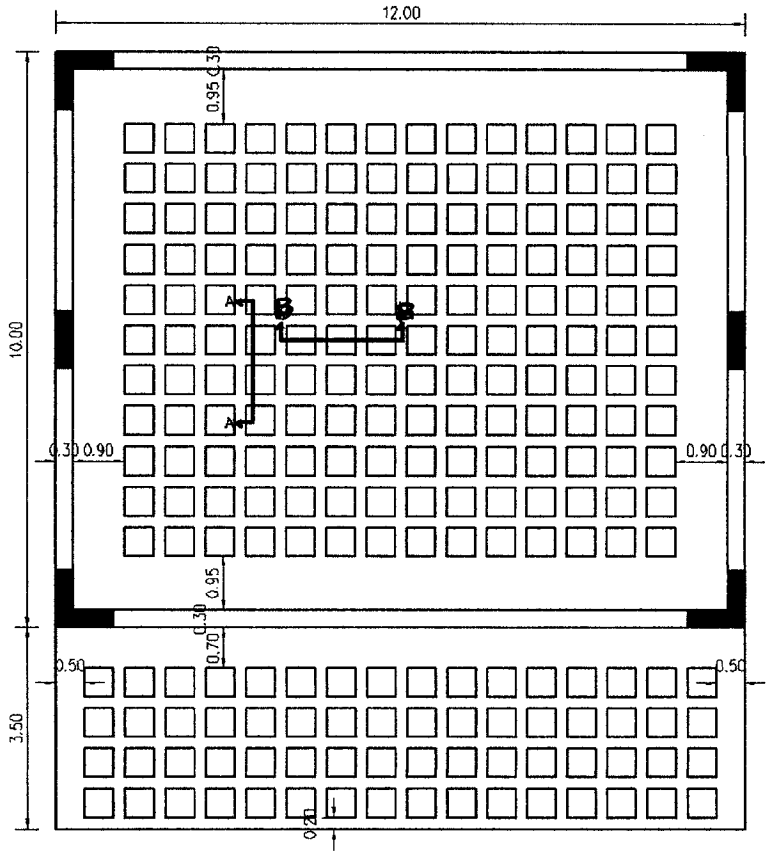
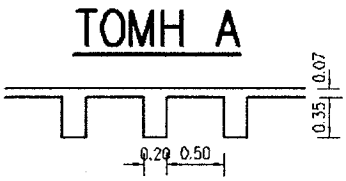
ΕΦΑΡΜΟΓΕΣ

1) Να υπολογισθούν οι πλάκες με νευρώσεις του σχήματος (με δυσμενείς φορτίσεις και χωρίς μείωση των ροπών ανοιγμάτων λόγω ροπών συστροφής). Οι πλάκες φέρουν φορτίο επικάλυψης 1.5 kN/m^2, κινητό φορτίο 5.0 kN/m^2. Στο άκρο του προβόλου προβλέπεται φορτίο ζαρντινιέρας 5.0 kN/m. Να σχεδιασθούν οι οπλισμοί σε κάτοψη (Κλ. 1:100) με αναπτύγματα και σε δυο τομές A-A και B-B (Κλ. 1:20). C20 / B500C, ψ=1. Οι συμπαγείς ζώνες μπορούν να αγνοηθούν για τον υπολογισμό του ι.β. της πλάκας.

(Απαραίτητη η χρήση συνδετήρων στις διαδοκίδες κατά τις δύο διευθύνσεις. Χρήση θεωρητικών ανοιγμάτων)

(βαθμ. 3,5)





1) Διαστάσεις

$l_x = \min\{\frac{t}{3}, 0.025\, l_n\} + 11.40 + \{\min \frac{t}{3}, 0.025\, l_n\}$

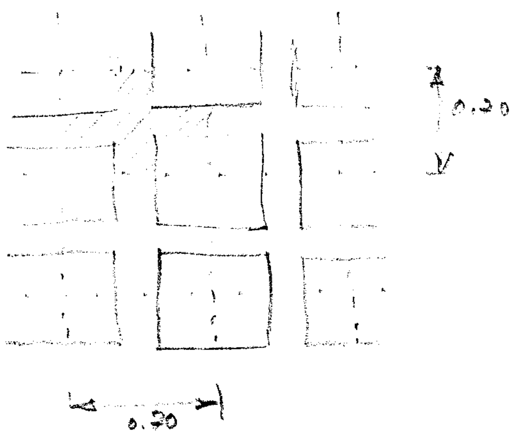
$= \min\{\frac{0.30}{3}, \underset{0.285}{0.025\times 11.40}\} + 11.40 + 0.10 = 11.60\ m \longrightarrow \alpha l_x = 1.0 \times 11.60 = 11.60\ m$

$l_y = \min\{\frac{0.30}{3}, \underset{0.235}{0.025\times 9.40}\} + 9.40 + 0.15 = 9.65\ m \longrightarrow \alpha l_y = 0.8 \times 9.65 = 7.72\ m$

$\therefore\ d \geq \frac{7.72}{25} = 0.31\ m$

Πρόβολος: $\frac{\alpha l}{d} = \frac{2.40 \times 3.65}{0.38} = 23 < 25$ ✓

2). Φορτία



$V = 0.70^2 \times 0.42 - 4\times 0.25 \times 0.25 \times 0.35 = 0.1183\ m^3$

$G = 0.1183 \times 25 = 2.9575\ kN$

$g_{I.B.} = \frac{2.9575}{0.70^2} = 6.036\ kN/m^2$

$g_{επ.} = 1.50\ kN/m^2$ $\qquad G = 5.0\ kN/m$

$q = 5.0\ kN/m^2$

$\varepsilon = \frac{l_{max}}{l_{min}} = \frac{11.60}{9.65} = 1.21 \simeq 1.20 \longrightarrow k_y = 0.838 \qquad k_x = 1 - k_y = 0.162$

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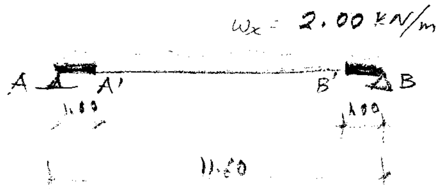
3). Στατική Επίλυση & Όπλιση κατά x

$w_d = 1.35\,(g_{I.B.} + g_{επ}) + 1.50\,q = 1.35\,(6.036 + 1.50) + 1.50 \times 5.0 = 17.67\ kN/m^2$

Θεωρώντας λωρίδα πλάτους 0.70 m : $w_{dx} = \underset{K_x}{0.162} \times \underset{w_d}{17.67} \times \underset{b}{0.70} = 2.00\ kN/m$



$V_A = V_B = 2.00 \times \frac{11.60}{2} = 11.60\ kN$

$V_{A'} = V_{B'} = 11.60 - 2.00 \times 1.00 = 9.60\ kN$

$M_m = 2.00 \times \frac{11.60^2}{8} = 33.6\ kNm$

Κάμψη: $M_{sd} = 33.6\ kNm$ $\qquad d_1 = 0.040\,m$

$\frac{h_f}{d} = \frac{7}{38} = 0.18 \qquad \frac{b}{b_w} = \frac{70}{20} = 3.5$

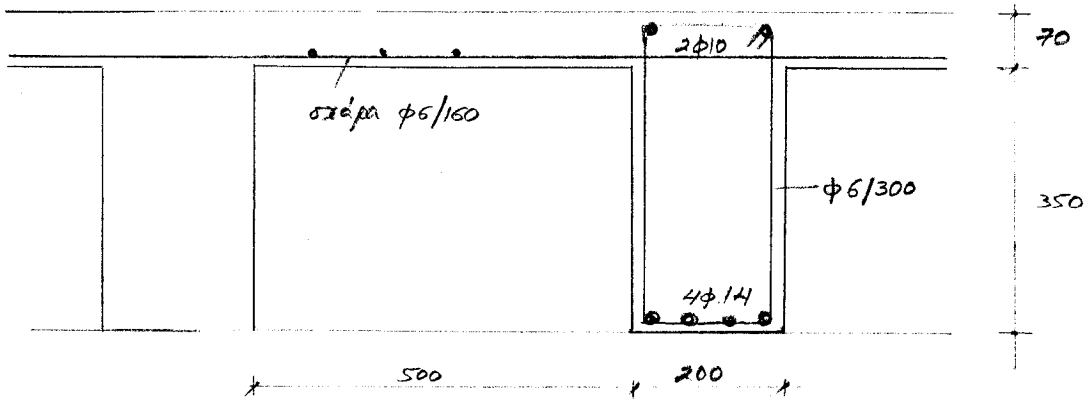
$\mu_{sd} = \frac{M_{sd}}{b d^2 f_{cd}} = \frac{33.6}{0.70 \times 0.38^2 \times 20000/1.50} = 0.025$ $\Big\} \longrightarrow 1000\,\omega =$ από γραμμική παρεμβολή

για $\frac{h_f}{d} = 0.15$ $\quad \frac{b}{b_w} = 3.5 \longrightarrow 1000\,\omega = 26$

$\quad\ \ 0.20 \qquad$ " $\qquad \longrightarrow \qquad = 26$ $\Big\} \longrightarrow 1000\,\omega = 26$

$A_{s1} = \omega\, b d \dfrac{f_{cd}}{f_{yd}} = 0.026 \times 70 \times 38 \times \dfrac{20/1.50}{500/1.15} = 2.12\ cm^2$

$\rightsquigarrow$ $4\phi 14$ ($= 6.15\ cm^2$) κάτω & $2\phi 10$ πάνω



Στην πλάκα τοποθετείται πλέγμα $\rho_{min} = 0.001$

$A_{s1}/\ell = 0.001 \times 100 \times 7 = 0.7\ cm^2/m$

ή $= 0.001\left(\dfrac{70 \times 7 + 20 \times 35}{0.70}\right) = 1.7\ cm^2/m$

} πλέγμα $\phi 6/160$ ($= 1.77\ cm^2/m$)

Διάτμηση

$V_{Rd2} = \frac{1}{2}\nu\, f_{cd} \cdot b_w \cdot 0.90d = 0.5 \times 0.6 \times \dfrac{20000}{1.50} \times 0.20 \times 0.90 \times 0.38 = 273.6\ kN >> V_{Sd}$

$\nu = 0.7 - \dfrac{f_{ck}}{200} = 0.7 - \dfrac{20}{200} = 0.6 > 0.50$

$V_{Rd1} = \tau_{Rd} \cdot k\,(1.20 + 40\rho_\ell) \cdot b_w \cdot d = 0.26 \times 10^3 \times 1.22 \times \left(1.20 + 40\,\dfrac{2\phi 14}{20 \times 38}\right) \times 0.20 \times 0.38 = 32.84\ kN$

$k = 1.6 - d = 1.6 - 0.38 = 1.22 > 1.0$

$V_A = V_B = 11.60 < V_{Rd1} = 32.84\ kN \rightsquigarrow$ δεν απαιτείται οπλισμός τέμνουσας.

Στο B': $V_{d,new} = 1.10\, V_{d,total}/n$

$= 1.10\, V_{d,total}/(1/0.70) = 0.77\, V_{d,total} = 0.77 \times 9.60 = 7.4\ kN << V_{Rd1}$ ($V_{B'}$)

άρα τοποθετούνται οι ελάχιστοι συνδετήρες στις περιοχές:

Αφού $V_{d,new} = 7.4\,kN < \frac{1}{5} V_{Rd2} = \frac{1}{5} \times 223.6 = 54.7\ kN$

$\rightsquigarrow s_{max} = 0.8d = 0.8 \times 380 = 304 \rightsquigarrow s_{max} = 300\ mm$

$\therefore \phi 6/300 \quad \rho_w = \dfrac{2 \times 0.28}{20 \times 30} = 0.000933 > \min \rho_w = 0.0007$ για C20/B500C

4) Στατική Επίλυση & Φόρτιση κατά y

για λωρίδα πλάτους 0.70 m

άνοιγμα: $q = g_{i.\beta.} + g_{\sigma\tau\rho} = (6.036 + 1.50) \times 0.70 \times 0.838 = 4.412\ kN/m$ (b, k_y)

$= 2.93$ "

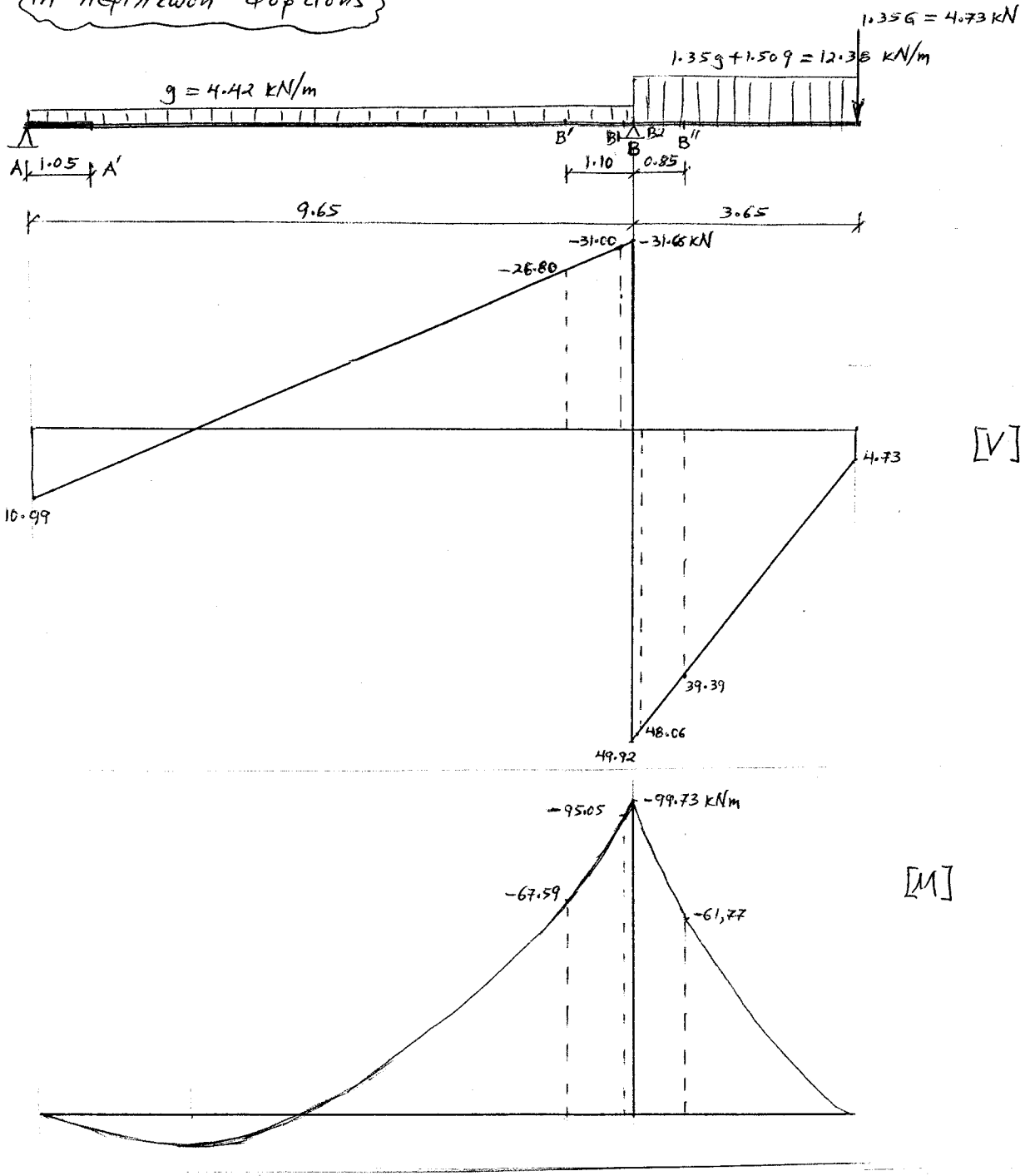
$q = 5.0 \times 0.70 \times 0.838$

πρόβολος: $g = (6.036 + 1.50) \times 0.70 = 5.28\ kN/m$

$q = 5.0 \times 0.70 = 3.50$ "

$G = 5.0 \times 0.70 = 3.50\ kN$

1η περίπτωση φόρτισης



$M_B = -12.38 \times \frac{3.65^2}{2} - 4.73 \times 3.65 = -99.73$ kNm

$M_{B''} = -12.38 \times \frac{2.80^2}{2} - 4.73 \times 2.80 = -61.77$ kNm

$V_A \cdot l - \frac{g \cdot l^2}{2} = -M_B \rightsquigarrow V_A = \frac{gl}{2} + \frac{M_B}{l} = 4.42 \times \frac{9.65}{2} - \frac{99.73}{9.65} = 10.99$ kN

$V_{B,l} \cdot l + \frac{gl^2}{2} = M_B \rightsquigarrow V_{B,l} = -\frac{gl}{2} + \frac{M_B}{l} = -4.42 \times \frac{9.65}{2} - \frac{99.73}{9.65} = -31.66$ kN

$V_{B,r} = 12.38 \times 3.65 + 4.73 = 49.92$ kN

$V_{B'} = -31.66 + 4.42 \times 1.10 = -26.80$ kN

$V_{B1} = -31.66 + 4.42 \times 0.15 = -31.00$ kN

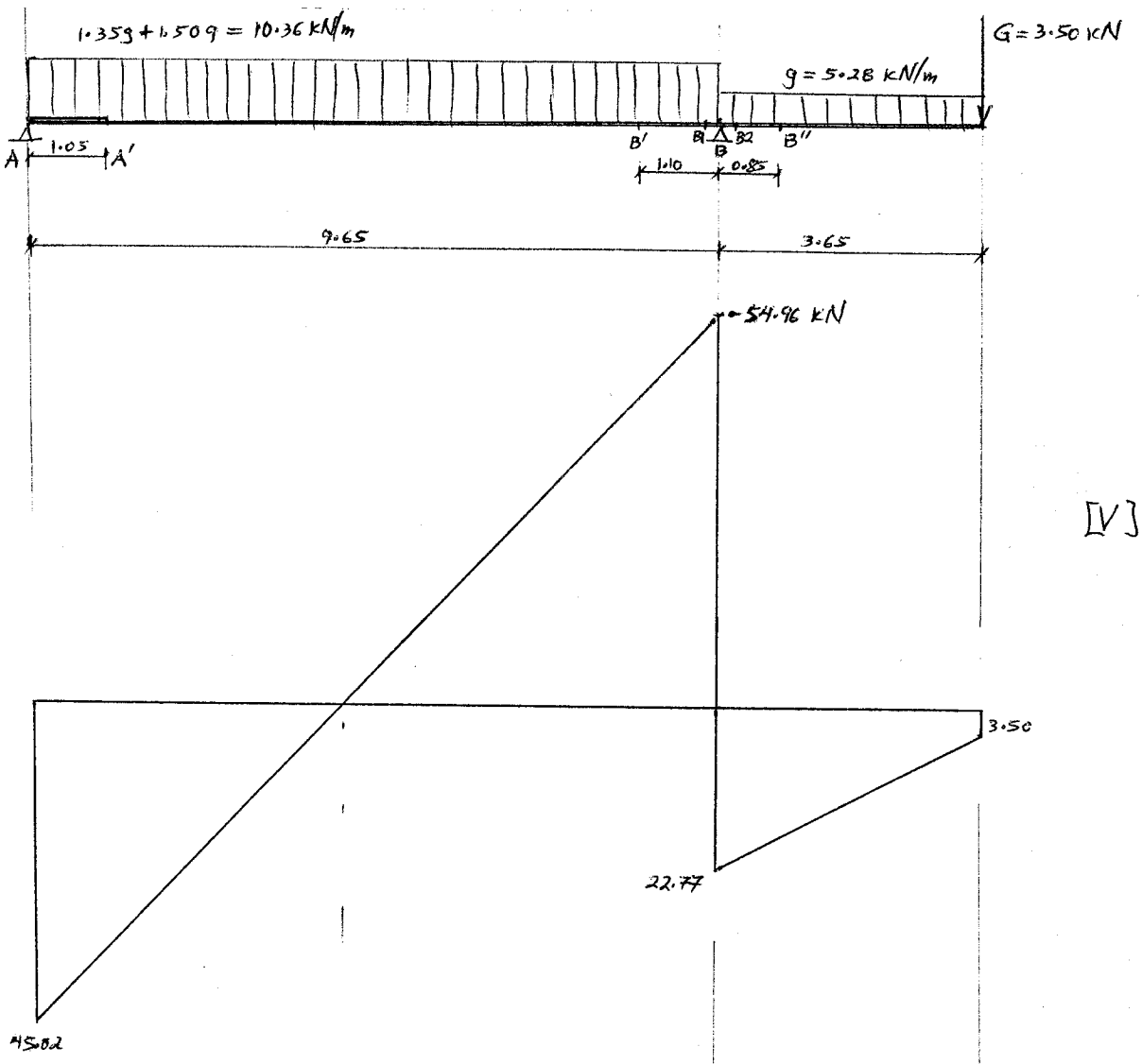
$V_{B2} = 12.38 \times 3.50 + 4.73 = 48.06$ kN

$V_{B''} = 12.38 \times (3.65 - 0.85) + 4.73 = 39.39$ kN

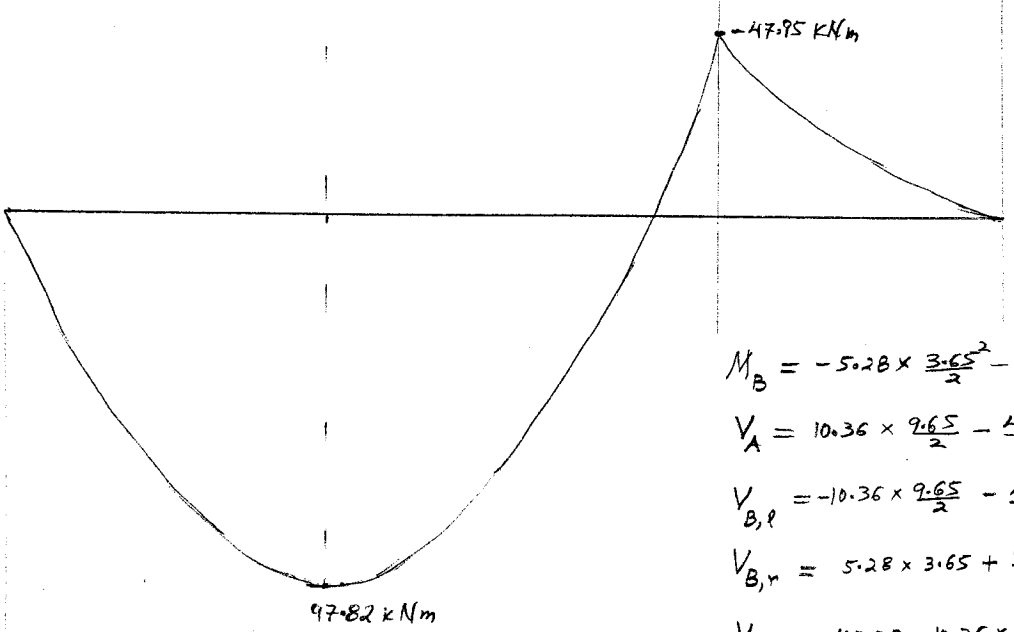
$M_{B'} = V_A(l - 1.10) + \frac{g(l - 1.10)^2}{2} = 10.99 \times (9.65 - 1.10) - 4.42 \frac{(9.65 - 1.10)^2}{2} = -67.59$ kNm

$M_{B1} = 10.99 \times (9.65 - 0.15) - 4.42 \frac{(9.65 - 0.15)^2}{2} = -95.05$ kNm

2η περίπτωση φόρτισης



[V]



[M]

$$M_B = -5.28 \times \frac{3.65^2}{2} - 3.50 \times 3.65 = -47.95 \text{ kNm}$$

$$V_A = 10.36 \times \frac{9.65}{2} - \frac{47.95}{9.65} = 45.02 \text{ kN}$$

$$V_{B,l} = -10.36 \times \frac{9.65}{2} - \frac{47.95}{9.65} = -54.96 \text{ kN}$$

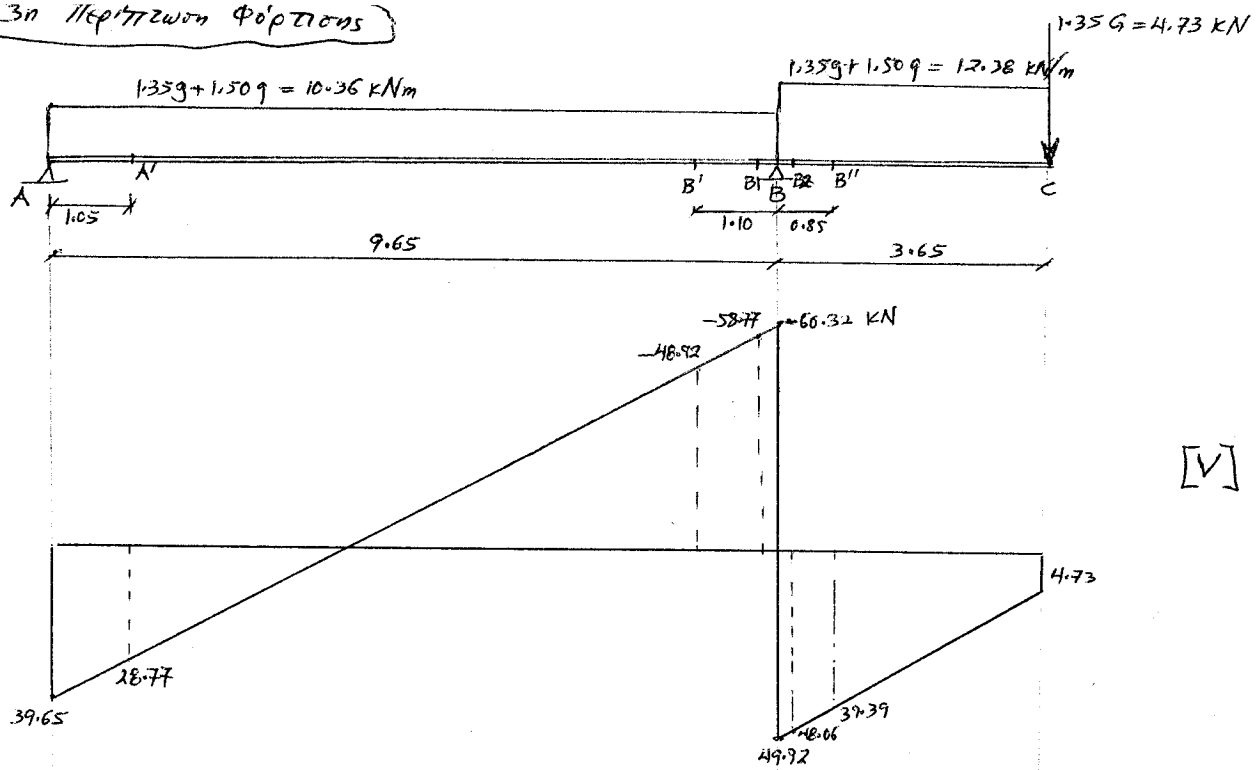
$$V_{B,r} = 5.28 \times 3.65 + 3.50 = 22.77 \text{ kN}$$

$$V_{A'} = 45.02 - 10.36 \times 1.05 = 34.14 \text{ kN}$$

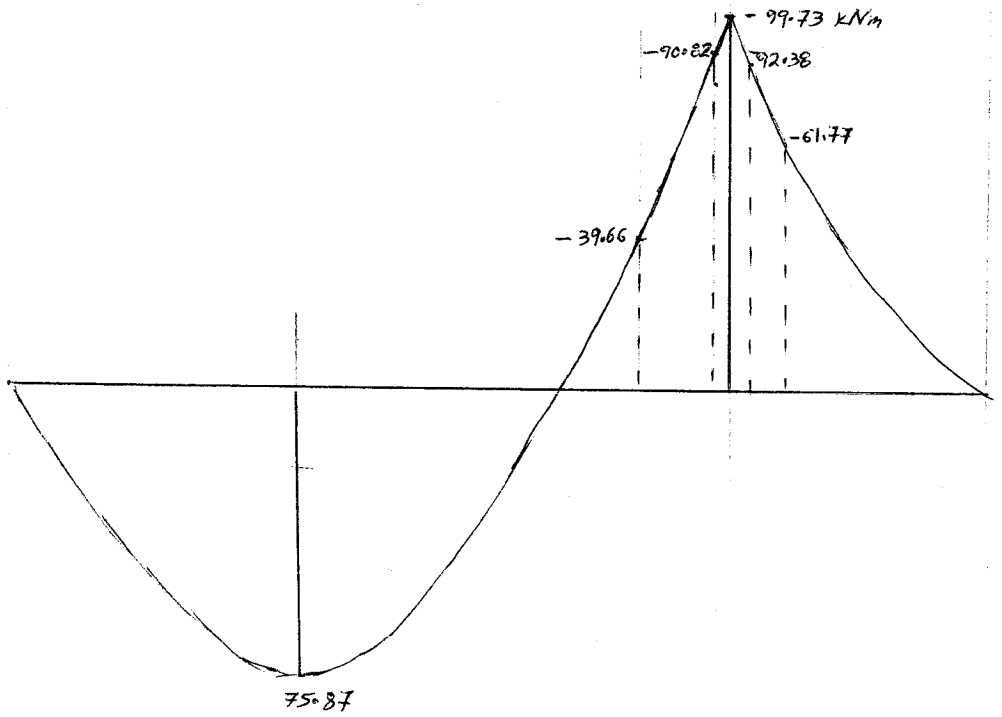
$$V_{B'} = -54.96 + 10.36 \times 1.10 = -43.56 \text{ kN}$$

$$\max M_{AB} = \frac{V_A^2}{2p} = \frac{45.02^2}{2 \times 10.36} = 97.82 \text{ kNm}$$

Επ περίπτωση φόρτισης



[V]



[M]

$M_B = -12.38 \times \frac{3.65^2}{2} - 4.73 \times 3.65 = -99.73\ kNm$

$M_{B2} = -12.38 \times \frac{3.50^2}{2} - 4.73 \times 3.50 = -92.38\ kNm$

$V_{B,r} = 12.38 \times 3.65 + 4.73 = 49.92\ kN$

$M_{B''} = -12.38 \times \frac{2.80^2}{2} - 4.73 \times 2.80 = -61.77$

$V_{B2} = 12.38 \times 3.50 + 4.73 = 48.06\ kN$

$V_{B''} = 12.38 \times (3.65 - 0.85) + 4.73 = 39.39\ kN$

$-V_{B,\ell} \cdot \ell_1 - \omega_1 \cdot \frac{\ell_1^2}{2} + M_B = 0 \longrightarrow V_{B,\ell} = \frac{-99.73}{9.65} - 10.36 \times \frac{9.65}{2} = -60.32\ kN$

$V_{B'} = -60.32 + 10.36 \times 1.10 = -48.92\ kN$

$V_{A'} = 39.65 - 10.36 \times 1.05 = 28.77\ kN$

$V_{B1} = -60.32 + 10.36 \times 0.15 = -58.77\ kN$

$V_A = 10.36 \times \frac{9.65}{2} - \frac{99.73}{9.65} = 39.65\ kN$

$\max M_{AB} = \frac{V_A^2}{2p} = \frac{39.65^2}{2 \times 10.36} = 75.87\ kNm$

$M_{B'} = V_A(\ell_1 - 1.10) - \omega_1 \frac{(\ell_1 - 1.10)^2}{2} = 39.65(9.65 - 1.10) - 10.36 \frac{(9.65 - 1.10)^2}{2} = -39.66\ kNm$

$M_{B1} = 39.65(9.65 - 0.15) - 10.36 \frac{(9.65 - 0.15)^2}{2} = -90.82\ kNm$

Κάμψη στο άνοιγμα

$M_{sd} = 97.82\ kNm$ $\quad d_1 = 0.0$

$\frac{h_f}{d} = \frac{7}{37} = 0.19$ $\quad \frac{b}{b_w} = \frac{70}{20} = 3.5$ $\Big\}$ $1000\omega = 82$

$\mu_{sd} = \frac{97.82}{0.70 \times 0.37^2 \times 20000/1.50} = 0.077$

$A_{s1} = 0.082 \times 70 \times 37 \times \frac{20/1.50}{500/1.15} = 6.51\ cm^2$

$\longrightarrow$ $4\phi 16$ $(= 8.04\ cm^2)$ κάτω & $2\phi 10$ πάνω

Κάμψη στον πρόβολο

B2: $\mu_{sd} = \frac{92.38 \times 10^{-3}}{0.70 \times 0.37^2} = 0.96\ MPa \longrightarrow \rho = 0.232\ \%$

$A_{s1} = \frac{0.232}{100} \times 70 \times 37 = 6.01\ cm^2 \longrightarrow 4\phi 14\ (= 6.15\ cm^2)$

B'': $\mu_{sd} = \frac{61.77 \times 10^{-3}}{0.20 \times 0.37^2} = 2.26 \longrightarrow \rho = 0.588\ \%$

$A_{s1} = \frac{0.588}{100} \times 20 \times 37 = 4.35\ cm^2$ από το άνοιγμα υπάρχουν $2\phi 16\ (= 4.02\ cm^2)$
$\therefore$ πρόσθετα $2\phi 12\ (= 2.26\ cm^2)$

B': $\mu_{sd} = \frac{67.59}{39.66} \frac{\times 10^{-3}}{0.20 \times 0.37^2} = 1.45 \longrightarrow \rho = 0.359\ \%$ ←

$A_{s1} = \frac{0.359}{100} \times 20 \times 37 = 2.66\ cm^2$

Διάτμηση

A': $V_{d,\text{περιο}} = 0.77 V_{A'} = 0.77 \times \frac{34.14}{28.57} = 22.1\ kN < V_{Rd1} = 32.84\ kN$

άρα ελάχιστοι συνδετήρες στις νευρώσεις $\longrightarrow \phi 6/300$

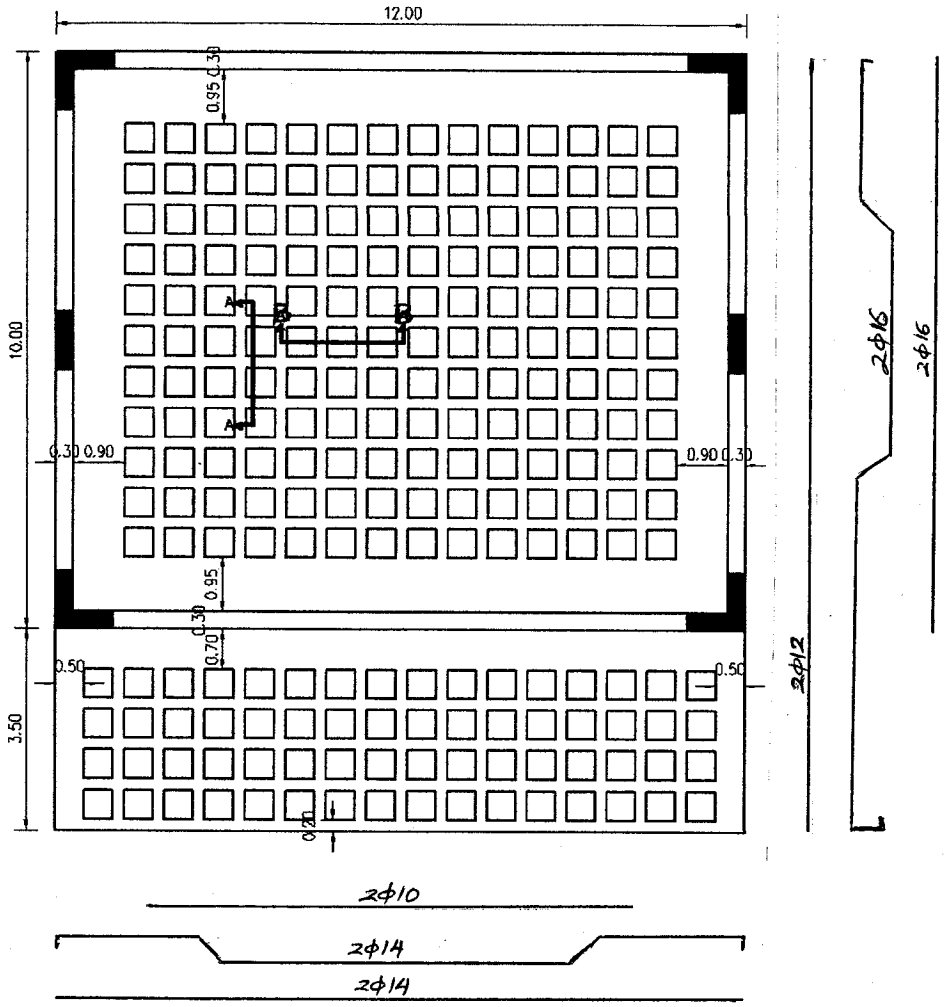
για $\phi 6/300 \longrightarrow V_{wd} = \frac{A_{sw}}{s_{max}} 0.9 d f_{ywd} = \frac{2 \times 0.28}{30} \times 0.9 \times 37 \times \frac{50}{1.15}\ \frac{kN}{cm^2} = 27.0\ kN$

$V_{Rd3} = V_{wd} + V_{\text{σδ}} = 27.0 + 32.8 = 59.8\ kN$

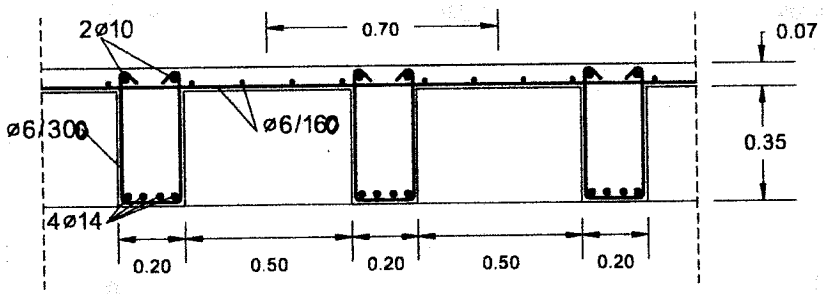
V_{Rd1} του πρόβολο

Επομένως σε όλη την πλάκα (εκτός ο ελάχιστος $\phi 6/300$ άφου πάνω)

$V_{sd} < 59.8\ kN$



Τομή Α-Α



Τομή Β-Β