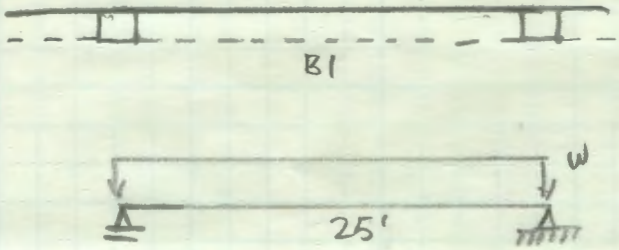
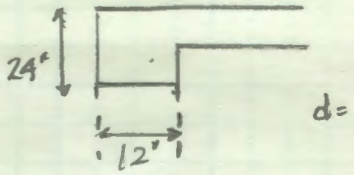
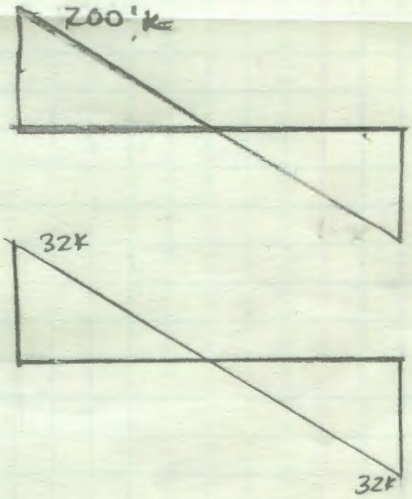




OUTPUT FROM RAM CONCEPT

M_u = 16'K $T_u = \frac{16(25)}{2} = 200'K$ T

V_u = 32K

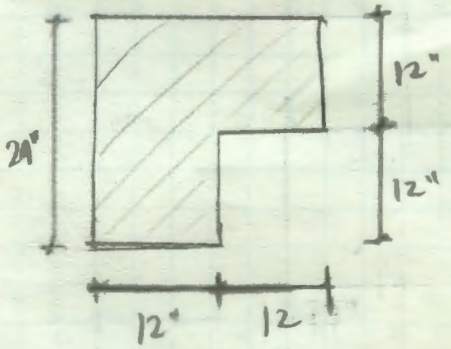


@ SUPPORT FACE

$T_u = 200 - \frac{200}{12.5}\left(\frac{21.5}{12}\right) = 171'K$

$V_u = 32 - \frac{32}{12.5}\left(\frac{21.5}{12}\right) = 27.4K$

TORSIONAL PROPERTIES



$4(12) = 48 \geq 24"$ OK!

$A_{cp} = (24)(12) + (12)(12) = 432\ in^2$

$P_{cp} = 24 + 24 + 12(4) = 96"$

$X_o = 12 - 2(1.75) = 8.5"$

$y_o = 24 - (2)(1.75) = 20.5"$

$A_{oh} = (8.5)(20.5) = 174.3\ in^2$

$A_o = 0.85(174.3) = 148\ in^2$

$P_h = 2(8.5 + 20.5) = 58"$

$T_u \le \phi \lambda \sqrt{f'c} \left(\frac{A_{cp}^2}{P_{cp}}\right)$, $N_u = 0$

$171 \le 0.75(\sqrt{6000})\left(\frac{432^2}{96}\right)/12000 = 9.4$ NO. GOOD! X

TORSION MUST BE CONSIDERED.

→ REDISTRIB. TORSION.

$T_u = \phi 4 \lambda \sqrt{f'c} \left(\frac{A_{cp}^2}{P_{cp}}\right) = 4(0.75)(\sqrt{6000})\left(\frac{576^2}{120}\right)/12000$

$= 37.6$ 'K

$$\sqrt{\left(\frac{V_u}{b_w d}\right)^2 + \left(\frac{T_u p_h}{1.7 A_{oh}^2}\right)^2} \le \phi \sqrt{10\sqrt{f'c}}$$

$$\sqrt{\left(\frac{27400}{(12)(22.3)}\right)^2 + \left(\frac{37.6(12000)(59)}{1.7(179.3)^2}\right)^2} \le 0.75(10\sqrt{6000})$$

518 psi ≤ 775 psi OK! ✓

→ REINFORCEMENT

TORSION - $A_t = \frac{T_u s}{2\phi A_o f_{yt} \cot\theta} = \frac{37.6(12000)s}{2(0.75)(149)(60000)\cot(45)} = 0.034$

SHEAR - $\phi V_c = 0.75(2)\sqrt{6000}(12)(22) = 30.7^k$

$A_v = \frac{(32 - 30.7)s}{0.75(60)22} = 0.0013s$

A_v NEEDED TIL $\frac{32}{12.5} = \frac{30.7}{12.5 - X} \Rightarrow X = 0.5'$ USE 1'

$\frac{A_{v+t}}{s} = \frac{A_v}{s} + 2\frac{A_t}{s} = 0.0013 + 2(0.034) = 0.069$ in²/in

ASSUME #4S $\frac{0.4}{0.069} = 5.9"$ → USE 4"

FLEXURE REINF

w_D = 2.25 KLF (SLAB) + 0.3 KLF (BM) + 0.525 KLF (S.D.) = 3.075 KLF

w_L = 0.9 KLF

$w_u = 1.2(3.075) + 1.6(0.9) = 3.8$ KLF

$M_u^- = \frac{3.8(25)^2}{11} = 215'K$

$M_u^+ = \frac{3.9(25)^2}{16} = 148'K$

$A_{s,REQ}^- \approx \frac{215}{4(22)} = 2.44$

$A_{s,REQ}^+ \approx \frac{148}{4(22)} = 1.68$

$A_{s\,MIN} = \frac{3\sqrt{4000}\,(12)(22}{60000} = 1.02\ in^2$

$\rho_{MAX} = 0.0273\ in^2$

$A_{s\,MAX} = 0.0273(12)(22) = 7.2\ in^2$

TRY (4) # 8's $A_s = 3.16\ in^2$ $d = 22"$

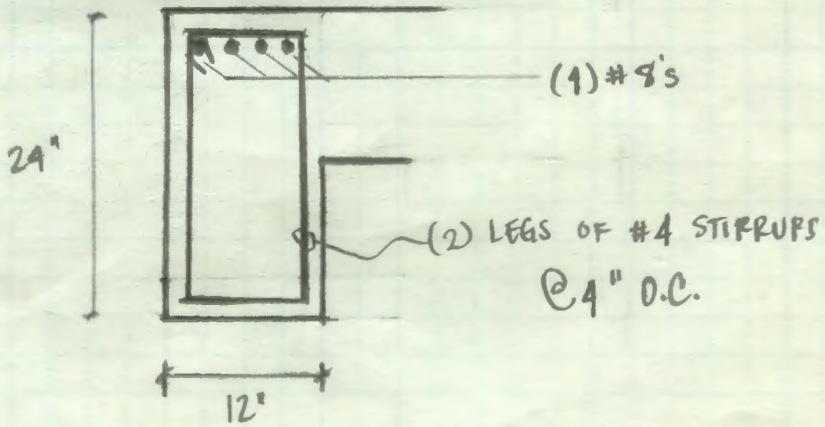
ASSUME $f_s \geq f_y$

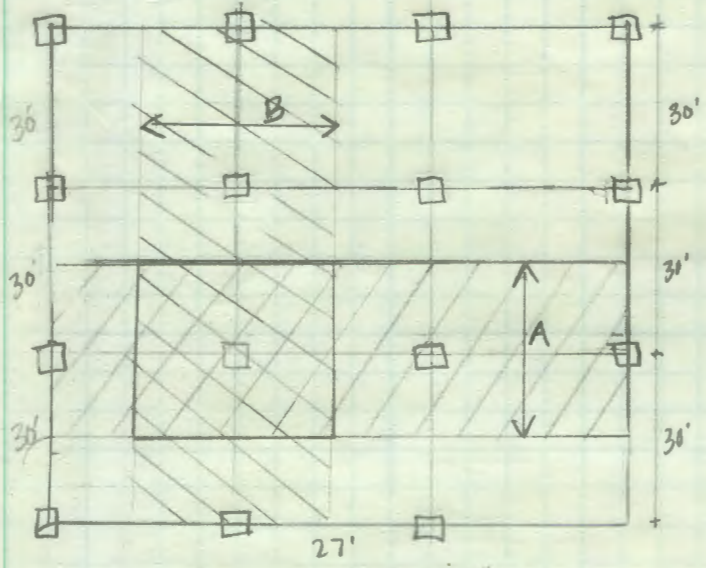
$\beta_1 = 0.75$

$a = \frac{3.16(60)}{0.85(6)(12)} = 3.1$ $\quad c = 4.13"$

$\varepsilon_s = \frac{0.003}{4.13}(22 - 4.13") = 0.013 > 0.00207$ STEEL YEILDS > 0.005 $\phi = 0.9$

$\phi M_n = 0.9(3.16)(60)(22 - \frac{3.1}{2})/12 = 290'K > 215'K$ OK! ✓





Assume 24"x24" columns

Location: Building 1
Level 6

Bay Sizes: 27' x 30'

Direct Design

- 3 spans ✓
- $\frac{30}{27} = 1.11 < 2$ ✓
- $w_L < 2w_D$ ✓

Minimum Slab depth

↳ $t = \frac{l_y}{33}$ → Table 9.5b

w/o drop panels
interior panels
w/o edge beams

$= \frac{(30'-2')12}{33}$

$= 10.2"$ → use 12" slab.

Loads

↳ Self Weight = $(1')(30')(151^{lb}/ft^3) = 4.5$ KLF

↳ Super Imposed Dead = 35 PSF x (30') = 1.05 KIF

↳ Live Load = 40 PSF x (30') = 1.20 KIF

↳ $W_u = 1.2(4.5+1.05) + 1.6(1.2)$

$= 8.58$ KIF

Frame Moments

↳ Frame A : $M_{DA} = \frac{(8.58)(28)^2}{8} = 840.8$ ft-K

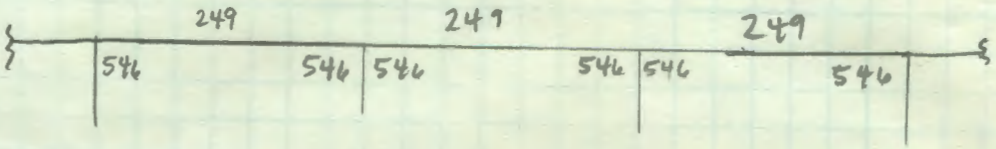
↳ Frame B : $M_{DB} = \frac{(8.58)(27-2)^2}{8} = 670.3$ ft-K

↳ Moment Distribution

- Note: The bays under consideration are representative bays for calculations. Therefore consider all spans interior for calculation.

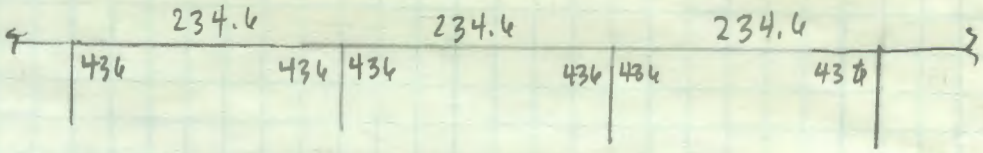
- $M_A^- = 0.65(840.8) = 546.5'K$

  $M_A^+ = 0.35(840.8) = 249.3'K$

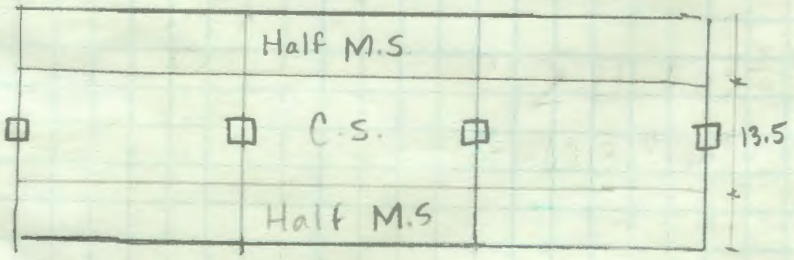


- $M_B^- = 0.65(670.3) = 435.7'K$

  $M_B^+ = 0.35(670.3) = 234.6'K$



↳ Determine Column & Middle Strips



Frame A

C.S.: $\frac{27'}{2}(12) = 162"$

M.S. $= [(30)(12) - 162"]/2$

$= 99"$

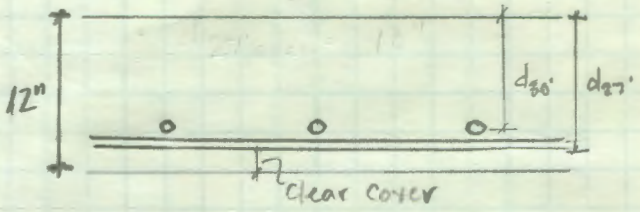
Frame B

C.S $= 162"$

M.S $= 162"/2$

$= 81"$

↳ Calculate d



Assume using #5 rebar

$d_{\#7\text{ span}} = 12" - 0.75" - \frac{0.625}{2} = 10.94"$

$d_{\#6\text{ span}} = 10.94" - 0.625" = 10.31"$

↳ See spSlab for Reinforcement design.

- Frame A M⁻ Sample Cales

- $M_o \times 12/b = \frac{-546(12)}{162} = 40.4 \frac{K\text{-in}}{in}$

- $M_n = \frac{M_o}{\phi} = \frac{-546}{0.9} = 606.7'K$

- $R = \frac{M_n}{bd^2} = \frac{(606.7)}{162(10.31)^2} = 422.8\ ^{lb}/_{in^2}$

- ρ; $R = \rho f_y \left(1 - 0.59\rho \frac{f_y}{f_c}\right)$

$422.8 = 40000\rho - 531000\rho^2$

$\rho = \frac{40000 \pm \sqrt{40000^2 - 4(531000)(422.8)}}{2(531000)}$

$= 0.00755 \rightarrow$ use

or

$= 0.08471$

- $A_s = \rho bd = 0.00755(162")(10.31") = 12.61\ in^2$

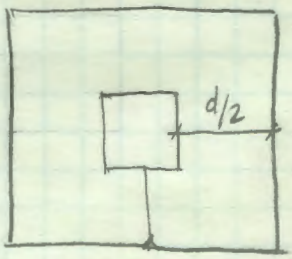
- $A_{s\,min} = 0.0018bt = 0.0018(162)(12) = 3.499\ in^2$

- $N = 12.61/0.31 = 40.68 \rightarrow$ use 41 Bars

- $N_{min} = \frac{b}{2t} = \frac{162}{2(12)} = 6.75$

Note: Refer to sp Slab for remaing reinforcement.

Punching Shear



$$d/2 = \frac{10.94"}{2} = 5.47"$$

$$b_o = 4[24" + 2(5.47)] = 139.8 \text{ in}$$

$$V_c = 4\sqrt{4000}\,(139.8)(10.94) = 386.8^K$$

$$\phi V_c = 0.75(386.8) = \underline{290^K}$$

$$w_u = 1.2(150 + 35) + 1.6(40) = 0.286 \text{ KSF}$$

$$V_u = w_u \cdot A_{ps} = (0.286)\left[(30)(27) - \frac{(24" + 10.94)^2}{144}\right] = \underline{229.2^K}$$

$$\phi V_c > V_u \quad (290^K > 229^K)$$

OK! ✓

System is designed to with stand Punching Shear.

↳ Deflections

Column Strip (Assume 67.5% goes to this strip)

$w_{DL} = \left(\frac{12}{12}\right)(150)(27)(0.675) = 2.73$ k/ft

$w_{LL} = (40)(27)(0.675) = 1.09$ k/ft

$I_{c.s.} = \frac{162(12)^3}{12} = 23328\ in^4$

$E_c = 57000\sqrt{4000} = 3604$ ksi

$\Delta_D = \frac{0.0026(2.73)(27)^4}{(3604)(23328)}(1728) = \underline{0.0775"}$

$\Delta_L = \frac{0.0048(1.09)(27)^4}{(3604)(23328)}(1728) = \underline{0.057"}$

Middle Strip (Assume 32.5% goes to this strip)

$w_{DL} = \left(\frac{12}{12}\right)(150)(30)(0.325) = 1.46$ k/ft

$w_{LL} = (40)(30)(0.325) = 0.59$ k/ft

$I_{M.S.} = \frac{81(12)^3}{12} = 11664\ in^4$

$E_c = 3604$ ksi

$\Delta_D = \frac{0.0026(1.46)(30)^4}{(3604)(11664)}(1728) = \underline{0.126"}$

$\Delta_L = \frac{0.0048(0.585)(30)^4}{(3604)(11664)}(1728) = \underline{0.0934"}$

Long Term Deflections

Column Strip

$$\Delta_{LT} = 3(\Delta_{DL} + 0.25\Delta_{LL}) = 3[0.0775 + 0.25(0.57)]$$
$$= 0.275"$$

Middle Strip

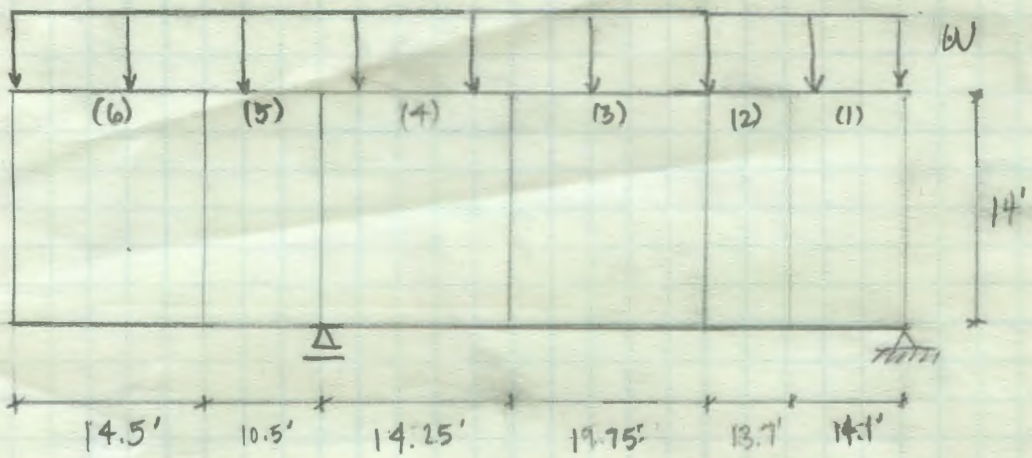
$$\Delta_{LT} = 3[0.126 + 0.25(0.0934)]$$
$$= 0.448$$

$$\Delta_{TL} = 0.275" + 0.448" = 0.723"$$

$$\Delta_{max} = 0.1(\Delta_D) + \Delta_{TL} + \Delta_{LL}$$
$$= 0.1(0.0775 + 0.126) + 0.723 + (0.057 + 0.0934)$$
$$= 0.89"$$

$$\Delta_{Allowable} = \frac{l}{240} < \frac{30(12)}{240} = 1.5"$$

$$0.89" < 1.5"$$



Bm = 97.6 K
COLS = 5K

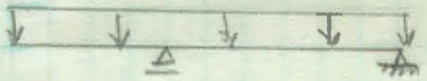
LOADING

W_{SD} = 35 PSF x 50' = 1.75 KLF

W_L = 80 PSF x 50' x 0.4 LLR = 1.6 KLF

W_{SW} = 1.68 KLF

$W_u = 1.2(1.75 + 1.68) + 1.6(1.6) =$ KLF



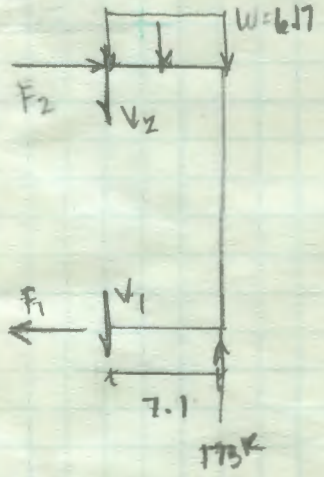
$\uparrow R_1 = 408$ $\uparrow R_2 = 173$

$\Sigma M_{R2} = (6.7)(86.75)\left(\frac{86.75}{2}\right) = 61.8R_1$

$R_1 = 408^K$

$R_2 = 173^K$

CUT 1



ΣF_y: $173 - (6.7)(7.1) = 125.4^K$

$V_1 = 62.7^K$

$V_2 = 62.7^K$

$\circlearrowleft \Sigma M_{V1} = (173)(7.1) = (14)(F_2) + (6.7)(7.1)\left(\frac{7.1}{2}\right)$

$F_2 = 75.7^K$

$F_1 = 75.7^K$

GROSS & CRACKED SECTION MOMENT OF INERTIA

→ $I_g = \frac{18(30)^2}{12} = \underline{\underline{40,500}}\ in^4$

→ I_{cr} i $B = \frac{18}{(6.57)(4)} = 0.685$

$$r = \frac{(6.57-1)\,4\,in^2}{6.57(4)} = 0.848$$

$$Kd = \left[\sqrt{2dB\left(1+\frac{rd'}{d}\right)+(1+r)^2} - (1+r)\right]/B$$

$$= \left[\sqrt{2(27)(0.685)\left(1+\frac{0.848(3)}{27}\right)+(1+0.848)^2} - (1+0.848)\right]/0.685$$

$$= 6.8"$$

$$I_{cr} = b(kd)^3/3 + nA_s(d-kd)^2 + (n-1)A'_s(kd-d')^2$$

$$= 18(6.8)^3/3 + (6.57)(4)(27-6.8)^2 + (6.57-1)(4)(6.8-3)^2$$

$$= \underline{\underline{12,932}}\ in^4$$

$$I_g/I_{cr} = \frac{40,500}{12,932} = 3.13$$

CRACKED MOMENT OF INERTIA

$$M_{cr} = \frac{f_r I_g}{y_t} = \frac{(671)(40,500)}{15"}/12000 = 151'K$$

(+) MOMENTS

$$\frac{M_{cr}}{M_D} = \frac{151}{167.2} = 0.903 \qquad I_{e,d} = (0.903)^3(40500) + \left[1-(0.903)^3\right]12,932$$

$$= \underline{\underline{33,230}}\ in^4$$

$$\frac{M_{cr}}{M_{SUS}} = \frac{151}{167.2+0.5(71.02)} = 0.745 \qquad I_{e_{SUS}} = (0.745)^3(40500) + \left[1-(0.745)^3\right]12932$$

$$= \underline{\underline{24,331}}\ in^4$$

$$\frac{M_{cr}}{M_{TOT}} = \frac{151}{167.2+71.02} = 0.634 \qquad I_{e_{DL}} = (0.634)^3(40500) + \left[1-(0.634)^3\right]12932$$

$$= \underline{\underline{19,958}}\ in^4$$

INITIAL & SHORT TERM DEFLECTIONS

$$K = 1.20 - 0.2\frac{M_0}{M_a} \quad ; \quad M_0 = \frac{w l_n^2}{8} = 195.3 \qquad M_a = \frac{w l_n^2}{14} = 111.6$$

$$K = 1.20 - 0.2\left(\frac{195.3}{111.6}\right)$$

$$= 0.85$$

$$\Delta_{id} = \frac{0.85\left(\frac{5}{48}\right)(167.2)(19.75)^2(1728)}{(4415)(33,230)} = 0.068"$$

$$\Delta_{i,SUS} = \frac{0.85\left(\frac{5}{48}\right)(202.7)(19.75)^2(1728)}{(4415)(24,331)} = 0.113"$$

$$\Delta_{i,DL} = \frac{0.85\left(\frac{5}{48}\right)(238.2)(19.75)^2(1728)}{(4415)(19,958)} = 0.161"$$

$$\Delta_{i,L} = \Delta_{i\,DL} - \Delta_{id} = 0.161" - 0.068" = 0.093" < \frac{l}{360} = \frac{(19.75)(12)}{360} = 0.66"$$

OK! ✓

5-YEAR DEFLECTIONS

$$\lambda = \frac{2.0}{1 + 50(0.0082)} = 1.42$$

$$\Delta_{cp} + \Delta_{SH} = \lambda \Delta_{i\,SUS} = 0.113(1.42) = 0.16"$$

$$\Delta_{cp} + \Delta_{SH} + \Delta_{iL} = 0.16" + 0.093" = 0.253"$$

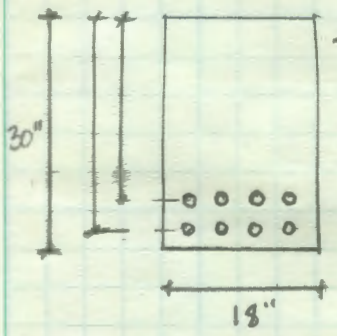
$$\Delta_{L,MAX} = \frac{l}{480} = \frac{(19.75)(12)}{480} = 0.494"$$

$$\boxed{0.253" < 0.494"} \quad \text{OK! ✓}$$

SPAN 4 - FLEXURE

→ REQ'D STEEL

$$A_s = \frac{M_u}{4d} = \frac{689}{4(27.5)} = 6.26 \text{ in}^2$$ TRY 2 ROWS (4) #8's $A_s = 6.32 \text{ in}^2$



→ FOR M_u^+

$d_t = 30" - 1.5" - 3/8" - 0.5" = 27.625"$

$d = 27.625 - 1.0" = 26.625"$ ⇒ USE 26.5"

$A_{s,MIN} < A_s$ OK! ✓

$A_{s,MAX} > A_s$ OK! ✓

} BY INSPECTION FROM BEFORE

→ ASSUME $f_s \geq f_y$

$$a = \frac{(6.32)(60)}{0.85(8)(18)} = 3.1 \qquad C = \frac{3.1}{0.65} = 4.77"$$

$$\varepsilon_s = \frac{0.003}{4.77}(26.5 - 4.77) = 0.0137 > 0.00207 = \varepsilon_s \text{ OK! } \checkmark$$
$$> 0.005 = \varepsilon_T \quad \therefore \phi = 0.9$$

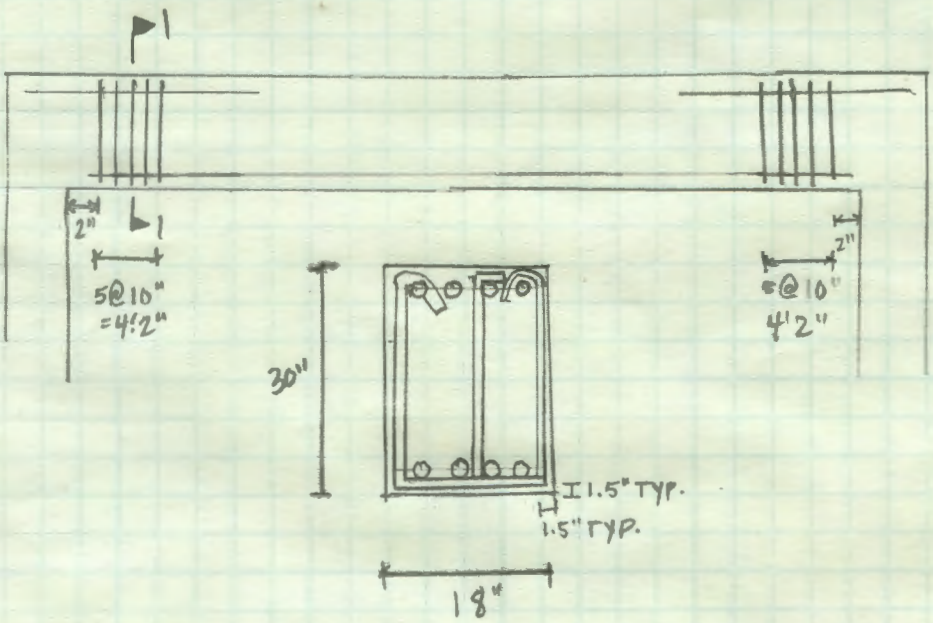
$$\phi M_N = 0.9(6.32)(60)(26.5 - \tfrac{3.1}{2})/12 = \underline{709 \text{ 'K}} > \underline{689 \text{ 'K}} \text{ OK! } \checkmark$$

USE 12) ROWS OF (4) #8's IN A 30"x18" BEAM

NOTE: $M_u^- = M_u^+$ ∴ USE SMALL DETAILING, EXCEPT M_u^-, PUT REINF ON TOP.

→ SPACING.

$S = 0.33(60)(27)/51 = 10.5" \Rightarrow$ USE 10"



SPAN 4 - SHEAR

→ $V_C = 2\sqrt{8000}(18)(26.5) = 85.3^K$

$\phi V_N = 0.5(0.75)(85.3) = 32^K < V_u = 96.7^K$ ∴ NEED STEEL

$V_{s\,d=26.5} = \frac{90.7}{0.75} - 85.3 = 35.63^K < 4\sqrt{8000}(18)(26.5) = 171^K$

→ MAXIMUM SPACING

$S = \frac{26.5}{2} = 13.25" \rightarrow$ USE 13"

→ MINIMUM REINF.

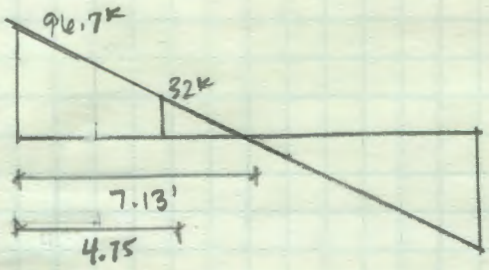
$A_{v\,MIN} = \begin{cases} 0.75\sqrt{8000}(18)(13)/60000 = 0.262 \text{ IN}^2 \rightarrow \text{CONTROLS} \\ 50(18)(13)/60000 = 0.195 \text{ IN}^2 \text{ IN}^2 \end{cases}$

∴ USE 3 LEGS OF $0.11 \text{ IN}^2 = 0.33 \text{ IN}^2 > 0.262 \text{ IN}^2$ OK! ✓

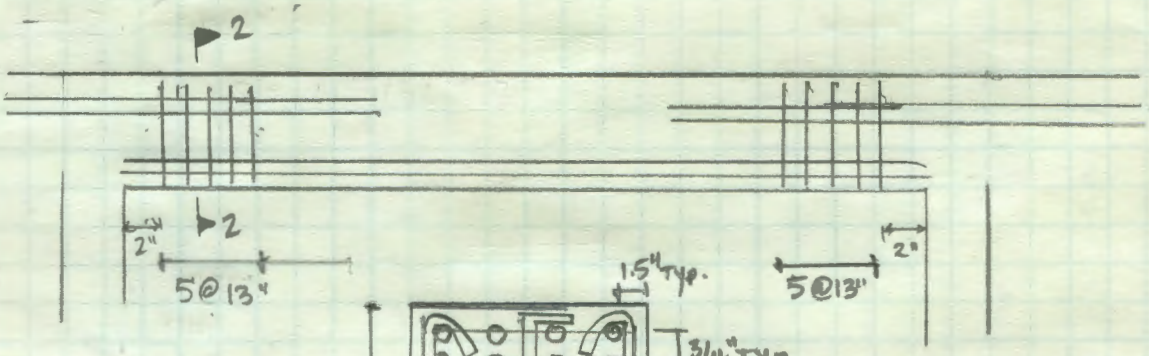
→ SPACING.

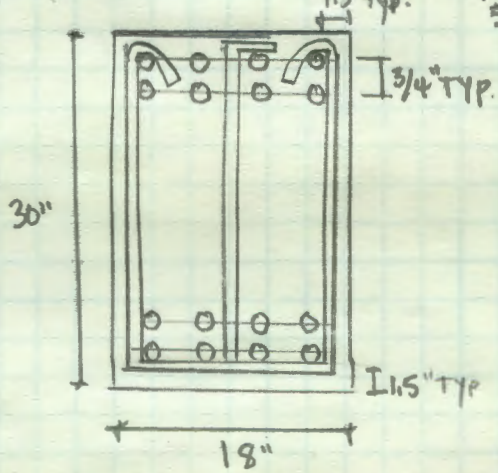
$S = (0.33)(60)(26.5)/35.6 = 14.7" \rightarrow$ USE 13"

SHEAR REINF. IS NEEDED UNTIL $V_u < 32^K$



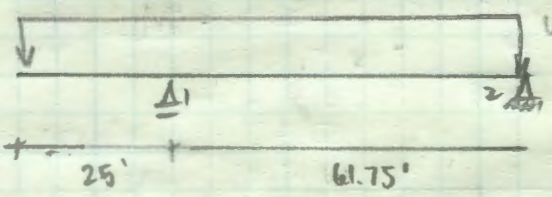
$$\frac{96.7}{7.13} = \frac{32}{X} \Rightarrow X = 4.75'$$





DESIGN OF CANTILEVER 30"x24"

SIMPLIFIED BEAM



$w = 5.34$ K/F $\quad M_1 = \frac{5.34(25)^2}{2} = 1669'K$

REQUIRED STEEL

ASSUME $d = 27"$

$A_s = \frac{1669}{4(27)} = 15.5\ in^2$ TRY (12) # 11's $A_s = 18.72\ in^2$ OK! ✓

$A_{s,MAX} = 0.0316(24)(27) = 20.5\ in^2$ OK! ✓

ASSUME $f_s = f_y$

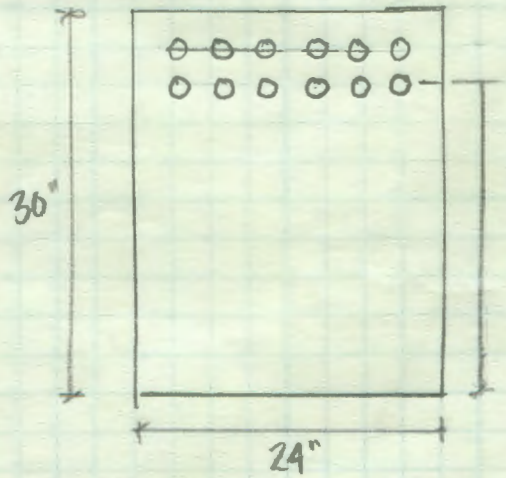
$a = \frac{4(60)}{0.85(8)(24)} = 1.47"$ $\quad C = \frac{1.47}{0.65} = 2.26"$

$\varepsilon_s = \frac{0.003}{2.26}(27-2.26) = 0.0328 > 0.00207$ OK!

$> 0.005 \therefore \phi = 0.9$

$\phi M_n = 0.9(18.72)(60)(27-\frac{1.47}{2})/12$

$= 2212.6'K > 1669'K$ OK! ✓



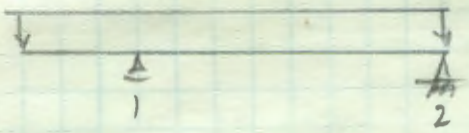
$d = 30" - 1.5" - 3/4" - 1.41 - \frac{1.41}{2} = 26"$

$\phi M_n = 2128'K$ OK! ✓

$\rho = \frac{18.72}{(24)(30)} = 0.026$

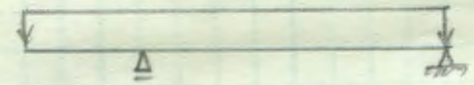
DEFLECTION

M_D



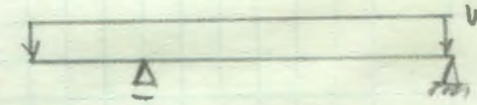
$W = 2.31$ KLF $M_1 = \frac{(2.31)(25)^2}{2} = \underline{\underline{721.9}}$ 'K

M_{SUS}



$W = 2.31 + (0.5)(1.6) = 3.11$ KLF $M_1 = \frac{(3.11)(25)^2}{2} = \underline{\underline{972}}$ 'K

M_{DL}



$W = 2.31 + 1.6 = 3.91$ KLF $M_1 = \frac{(3.91)(25)^2}{2} = \underline{\underline{1222}}$ 'K

$I_g = \frac{(24)(30)^3}{12} = 54{,}000$ IN^4

$I_{cr} \Rightarrow B = \frac{24}{(5.98)(18.72)} = 0.214$

$r = \frac{(6.57-1)(18.72)}{6.57(18.72)} = 0.848$

$Kd = \frac{\sqrt{2(26)(0.214)+1}-1}{0.214} = 12$"

$I_{cr} = \frac{24(12)^3}{3} + 5.69(18.72)(26-12)^2 = 34701$ IN^4 $\frac{I_g}{I_{cr}} = \frac{54000}{34701} = 1.56$

$M_{cr} = \frac{(671)(54000)}{15}/12000 = 201.3$ 'K

$\frac{M_{cr}}{M_D} = \frac{201.3}{721.9} = 0.74$ $I_{e_D} = (0.74)^3(54000) + [1-(0.74)^3]34701 = 42521$

$\frac{M_{cr}}{M_{SUS}} = \frac{201.3}{972} = 0.207$ $I_{e_{SUS}} = (0.207)^3(54000) + [1-(0.207)^3]34701 = 34.872$

$\frac{M_{cr}}{M_{DL}} = \frac{201.3}{1222} = 0.165$ $I_{e_{DL}} = (0.165)^3(54000) + [1-(0.165)^3]34701 = 34787$

SHORT TERM

$$\Delta_{i\,D} = \frac{2.4\left(\frac{5}{48}\right)(721.9)(25)^2(1728)}{(5098)(425211)} = 0.899"$$

$$\Delta_{i\,SUS} = \frac{2.4\left(\frac{5}{48}\right)(972)(25)^2(1728)}{(5098)(34,972)} = 1.48"$$

$$\Delta_{i\,D+L} = \frac{2.4\left(\frac{5}{48}\right)(1222)(25)^2(1728)}{(5098)(34787)} = 1.86"$$

$$\Delta_i = \Delta_{i\,D+L} - \Delta_{i\,D} = 1.86 - 0.899 = 0.96"$$

$$\Delta_{L,MAX} = \frac{L}{360} = \frac{25(12)}{360} = 0.833" < 0.96"$$ NO GOOD! X

TRY A BIGGER CROSS SECTION 24"x36"

DESIGN OF CANTILEVER

TRY 24"x36" $W_D = \frac{24" \times 36"}{144} \cdot \frac{150}{1000} = 0.9$ KLF

$W_T = 1.2(0.9 + 1.75) + 1.6(1.6) = 5.74$ KLF

$M_1 = \frac{(5.74)(25)^2}{2} = 1794$ K-FT

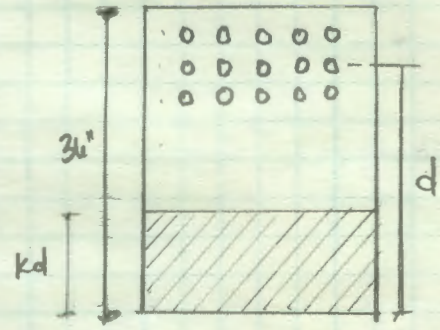
REQUIRED STEEL

ASSUME d= 32"

$A_s = \frac{1794}{4(32)} = 14.0$ IN^2

$A_{s,MAX} = 0.0316(24)(32) = 24.27$ IN^2

TRY (3) ROWS OF (5) #11's $A_s = 23.4$ IN^2



$d = 36 - 1.5" - 3/8" - 1.41" - 1" - 1.41"/2 = 31.7"$

ASSUME $f_s \geq f_y$

$a = \frac{(23.4)(60)}{0.85(8)(24)} = 8.6"$ $\quad c = 8.6"/0.85 = 13.2"$

$\varepsilon_s = \frac{0.003}{13.2}(31.7 - 13.2) = 0.0042 > 0.00207$ OK! ✓ STEEL YEILDS

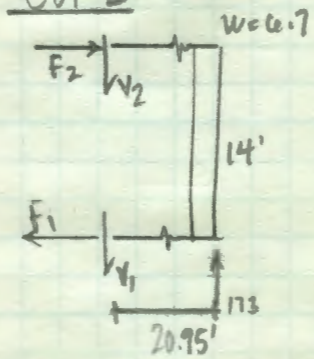
< 0.005

$\phi = 0.65 + 0.25\left(\frac{0.0042 - 0.00207}{0.005 - 0.00207}\right) = \underline{0.83}$

$\phi M_n = 0.83(23.4)(60)(31.7 - \frac{8.6}{2})/12 = 2661'K > 1794'K$ OK! ✓

USE 36"X24" w/ (3) ROWS OF (5) #11's $A_s = 23.4$ IN^2

CUT 2



$\Sigma F_y = 173 - (6.7)(20.95) = 32.6^K$

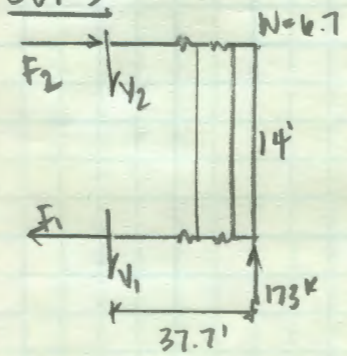
$V_1 = V_2 = 16.3^K$

$\circlearrowleft \Sigma M_{V_1} = (173)(20.95) = 14F_2 + (6.7)(20.95)\left(\frac{20.95}{2}\right) = 0$

$F_1 = -158.9^K$

$F_2 = 158.9^K$

CUT 3



$\Sigma F_y = 173 - 6.7(37.7) = -79.6^K$

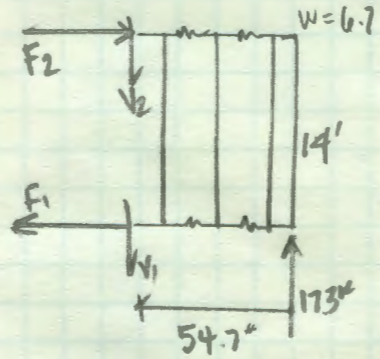
$V_1 = V_2 = -39.8^K$

$\circlearrowleft \Sigma M_{V_1} = (173)(37.7) = 14F_1 + (6.7)(37.7)\left(\frac{37.7}{2}\right) = 0$

$F_1 = -125.8^K$

$F_2 = 125.8^K$

CUT 4



$\Sigma F_y = 173 - (6.7)(54.7) = -193.3$

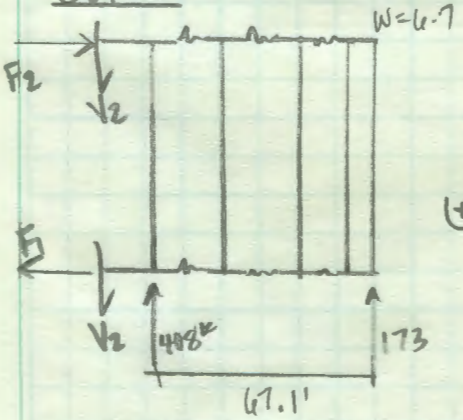
$V_1 = V_2 = -96.7^K$

$\circlearrowleft \Sigma M_{V_1} = 173(54.7) = 14F_2 + (6.7)(54.7)\left(\frac{54.7}{2}\right) = 0$

$F_1 = 40^K$

$F_2 = -40$

CUT 5



$\Sigma F_y = 408 + 173 - (6.7)(67.1) = 131.4^K$

$V_1 = V_2 = 65.7^K$

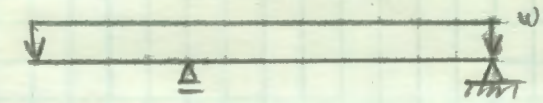
$\circlearrowleft \Sigma M_{V_1} = (173)(67.1) + (408)(5.25) = 14F_2 + 6.7(67.1)\left(\frac{67.1}{2}\right) = 0$

$F_1 = 95^K$

$F_2 = -95^K$

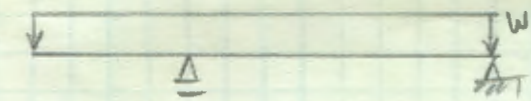
DEFLECTION

M_D



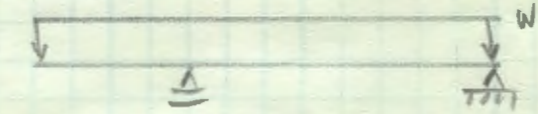
$$M_1 = \frac{(2.65)(25)^2}{2} = 828\ 'K$$

M_{SVS}



$$M_1 = \frac{(3.45)(25)^2}{2} = 1078\ 'K$$

M_{DTL}



$$M_1 = \frac{(4.25)(25)^2}{2} = 1328\ 'K$$

$$I_g = \frac{(24)(36)^3}{12} = 93312\ IN^4$$

CRACKED MOMENT OF INERTIA

$$B = \frac{24}{5.69(23.4)} = 0.180$$

$$r = \frac{(5.69-1)(23.4)}{5.69(23.4)} = 0.848$$

$$Kd = \frac{\sqrt{2(31.7)(0.180)+1} - 1}{0.180} = 14.1\ "$$

$$I_{cr} = \frac{(24)(14.1)^3}{3} + 5.69(23.4)(31.7-14.1)^2 = 63,669\ IN^2$$

$$M_{cr} = \frac{f_r I_g}{y_t} = \frac{(671)(93312)}{18"} / 12000 = 290\ 'K$$

EFFECTIVE MOMENT OF INERTIA

$\frac{M_{cr}}{M_D} = \frac{290}{828} = 0.35$ $\quad I_{e_D} = (0.35)^3(93312) + [1-(0.35)^3]63669 = 64940\ IN^4$

$\frac{M_{cr}}{M_{SVS}} = \frac{290}{1078} = 0.27$ $\quad I_{e,SVS} = (0.27)^3(93312) + [1-(0.27)^3]63669 = 64253$

$\frac{M_{cr}}{M_{DTL}} = \frac{290}{1328} = 0.218$ $\quad I_{e,DTL} = (0.218)(93312) + [1-(0.218)^3]63669 = 63,976$

SHORT TERM DEFLECTION

$K = 2.4$ (TABLE 10-3 ACI 318

$\rightarrow \Delta_{i,D} = \dfrac{2.4\left(\frac{5}{48}\right)(428)(25)^2(1728)}{(5098)(64940)} = 0.675"$

$\rightarrow \Delta_{i,SUS} = \dfrac{2.4\left(\frac{5}{48}\right)(1078)(25)^2(1728)}{(5098)(64253)} = 0.889"$

$\rightarrow \Delta_{i,D+L} = \dfrac{2.4\left(\frac{5}{48}\right)(1328)(25)^2(1728)}{(5098)(63.976)} = 1.08"$

$\rightarrow \Delta_{i,L} = \Delta_{i,D+L} - \Delta_{i,D} = 1.08 - 0.675 = \underline{0.41"}$

ALLOWABLE DEFLECTIONS

→ LIVE LOAD

$\dfrac{l}{360} = \dfrac{25(12)}{360} = \underline{0.833"} > \Delta_{i,D} = 0.41"$ OK! ✓

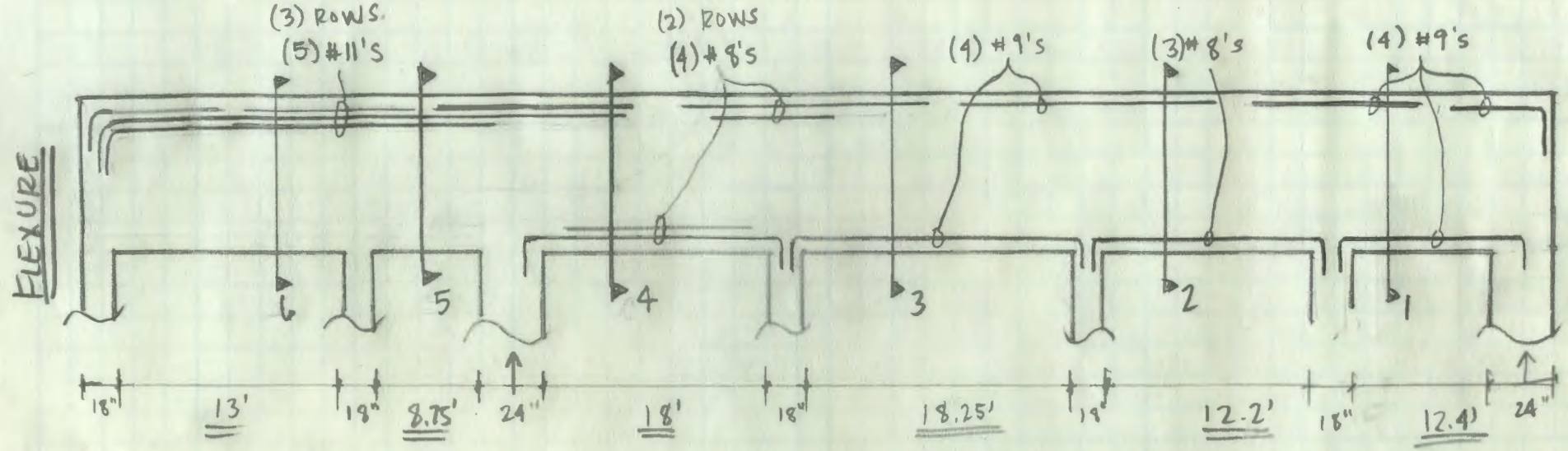
→ TOTAL LOAD (D+L)

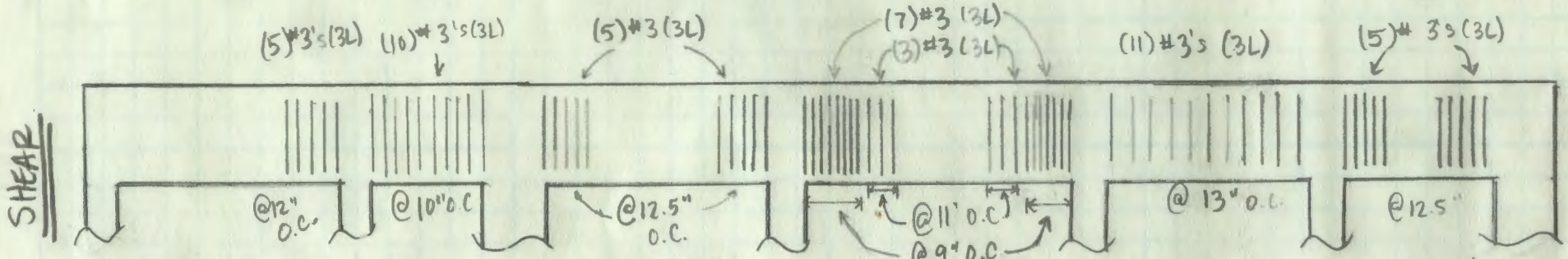
$\dfrac{l}{240} = \dfrac{(25)(12)}{480} = \underline{1.25"} > \Delta_{i,D+L} = 1.08"$ OK! ✓

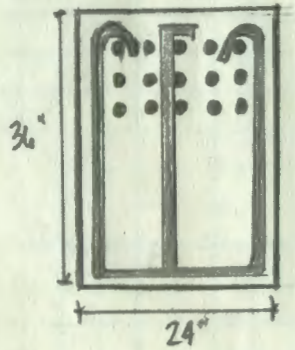
LONG. TERM DEFLECTIONS (5 YEARS)

$\lambda = \dfrac{2.0}{1+50(0.0271)} = 0.949 < 1.0$ LONG TERM IS OK! ✓

TOP CHORD FLEXURAL & SHEAR REINFORCEMENT
(LEVEL 9)



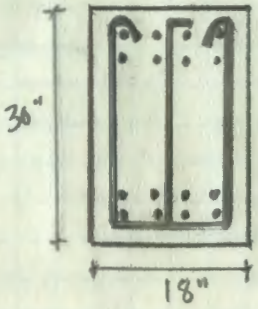




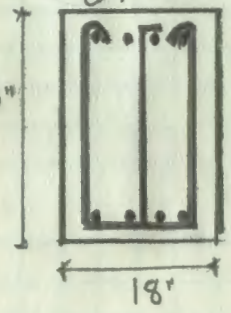
SEC 6

(SAME AS "6")

SEC. 5



SEC. 4



SEC 3

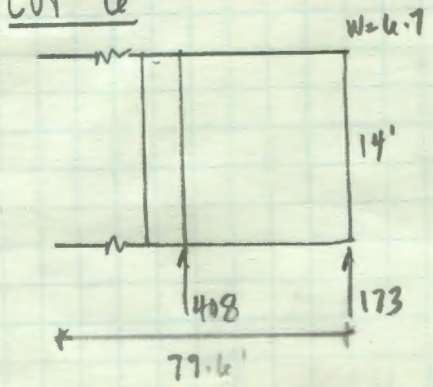
(SAME AS "3")

SEC E 2

(SAME AS "3")

SEC 1

Cut 6



$\Sigma F_y = 408 + 173 - 6.7(79.6) = 47.7^K$

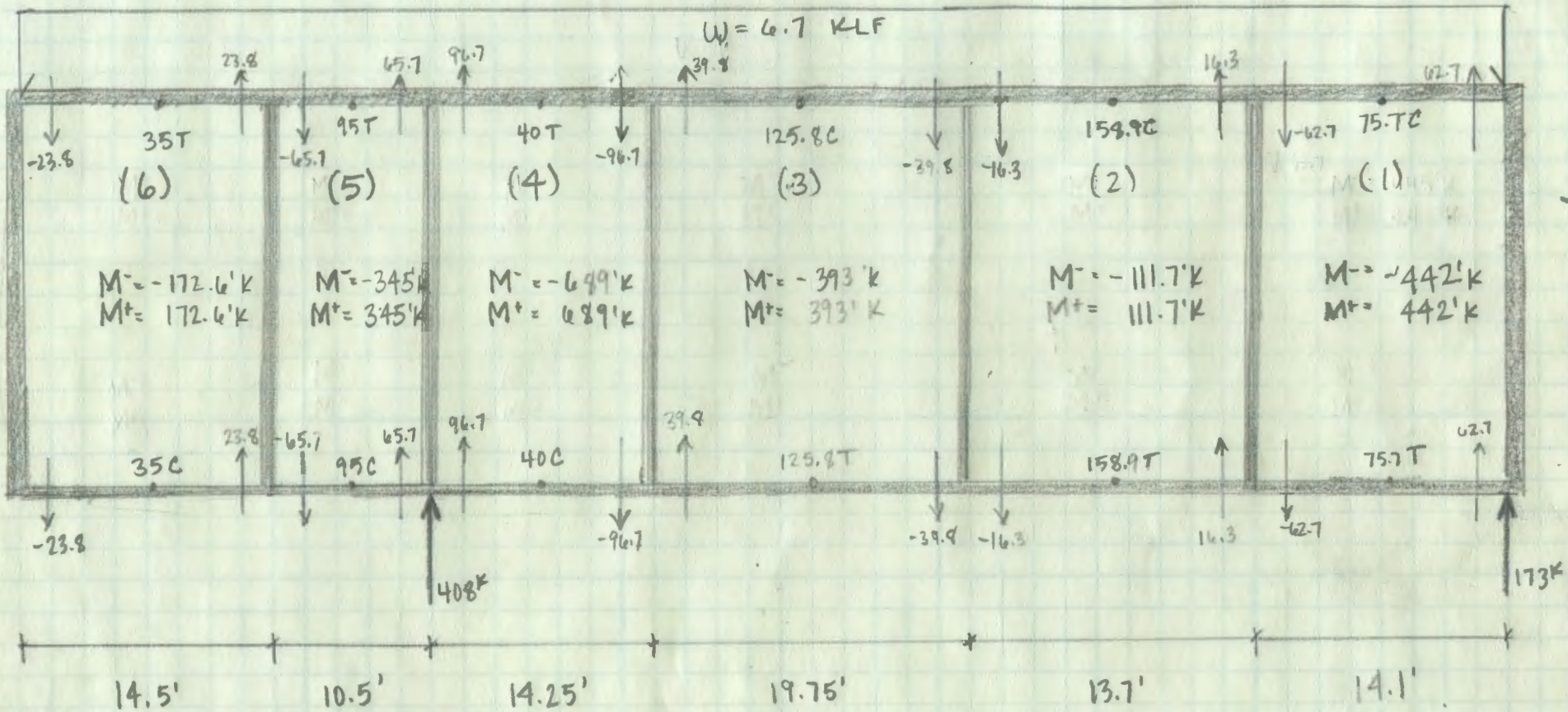
$V_1 = V_2 = 23.8$

$\circlearrowleft \Sigma M_{V_1} = (173)(79.6) + (408)(17.75) = 6.7(79.6)\left(\frac{79.6}{2}\right) + 14F_2$

$F_1 = -35^K$

$F_2 = 35^K$

TRUSS FRAME GD
(LEVEL 9)



CHRIS DUNLAY | TRUSS DESIGN | FINAL REPORT

BEAM DESIGN

SPAN 1 - FLEXURE

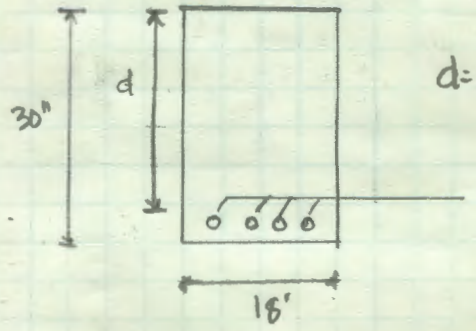
→ ESTIMATE SIZE: TRY $b = \frac{3}{5}d$

$$d^3 = 20(442)\frac{5}{3} \Rightarrow d = 24.5 \text{ IN}$$

$h = d + 2.5 = 27$ IN $\quad \therefore$ USE $h = 30"$ $b = 18"$ $d =$

→ REQ'D STEEL

$$A_s = \frac{M_u}{4d} = \frac{442}{4(27.5)} = 4.02 \text{ IN}^2 \quad \therefore \text{ USE (4) \#9's } \quad A_s = 4 \text{ IN}^2$$



$$d = 30" - 1.5" - 3/8" - \frac{9/8}{2} = 27"$$

→ $A_{s,MIN} = \begin{cases} \dfrac{3\sqrt{8000}(18)(27)}{60{,}000} = 2.17 \text{ IN}^2 \\ \dfrac{200(18)(27)}{60{,}000} = 1.62 \text{ IN}^2 \end{cases}$

$A_s > A_{s,MIN}$ OK! ✓

→ $A_{s,MAX} = \rho \cdot b \cdot d \quad ; \quad \rho = 0.85(0.65)\frac{8}{60}\left(\frac{0.003}{0.003+0.004}\right) = 0.0316$ ($f'_c = 8$ KSI)

$= 0.0316(18)(27) = 15.3 \text{ IN}^2 < A_s$ OK! ✓

→ ASSUME $f_s \geq f_y$

$$a = \frac{(4)(60)}{0.65(8)(18)} = 1.96" \qquad c = \frac{1.96}{0.65} = 3.02"$$

$$\varepsilon_s = \frac{0.003}{3.02}(27 - 3.02) = 0.0238 > \varepsilon_y = \frac{60}{29000} = 0.00207 \quad \text{OK! ✓}$$

$> \varepsilon_t = 0.005 \quad \therefore \phi = 0.9$

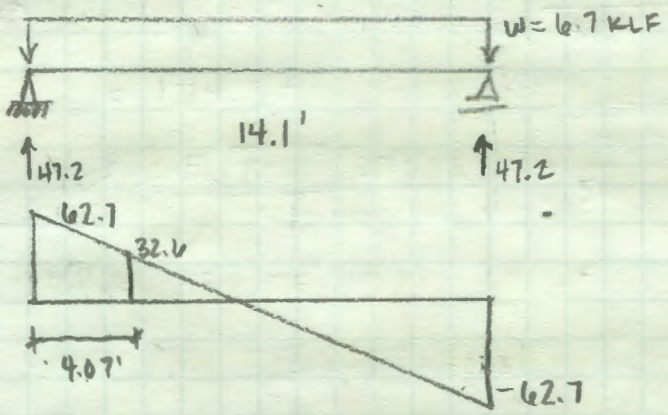
$$\phi M_n = 0.9(4)(60)\left(27 - \frac{1.96}{2}\right)/12 = \underline{476.3 \text{ K}} > \underline{442 \text{ K}} \quad \text{OK! ✓}$$

USE (4) #9's IN A 30" X 18" BEAM

SPAN 1 - SHEAR

$\rightarrow V_c = 2\sqrt{8000}(18)(27)/1000 = 86.9^K$

$\phi V_n = 0.5(0.75)(86.9) = 32.6^K < V_u = 62.7$ ∴ NEED STEEL



$V_S = -\frac{V_u}{\phi} - V_c = \frac{62.7}{0.75} - 86.9 = -3.3$

∴ SHEAR REINF. IS NEEDED UNTIL $V_u < 32.6$

$V_u < 32.6$ @ $\frac{62.7}{7.05} = \frac{32.6}{X} \Rightarrow X = 4.07'$ FROM CENTER LINE

$V_S = 8\sqrt{8000}(18)(27)/1000 = 348^K$

→ MAXIMUM SPACING

$V_s < 4\sqrt{8000}(18)(27) = 174$

$S = \frac{27}{2} = 13.5" \rightarrow$ USE 13"

→ MINIMUM REINF.

$A_{v,MIN} >$ MAX $\begin{cases} 0.75\sqrt{8000}(18)(13)/60000 = 0.262\ in^2 \rightarrow \text{CONTROLS} \\ 50(18)(14)/60000 = 0.195\ in^2 \end{cases}$

∴ USE 3 LEGS $0.11 in^2 = 0.33 in^2 > 0.262 in^2$

→ SPACI

SPAN 2 FLEXURE

$M_u = 111.7$ 'K

$V_u = 16.3^K$

→ REQ'D STEEL

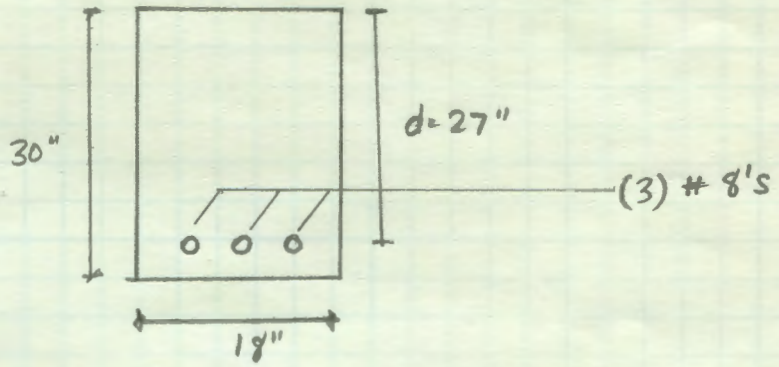
$$A_s = \frac{M_u}{\phi d} = \frac{111.7}{.9(27.5)} = 1.02\ IN^2 \therefore \text{CHECK } A_{s,MIN}$$

→ $A_{s,MIN}$

$$A_{s\,MIN} = \frac{3\sqrt{8000}(18)(27)}{60{,}000} = 2.17\ IN^2 \rightarrow \text{USE } A_s = 2.17\ IN^2$$

$$\frac{200\sqrt{8000}(18)(27)}{60{,}000} = 1.62\ IN^2$$

∴ TRY (3) #8's $A_s = 2.37\ IN^2$



→ ASSUME $f_s \geq f_y$

$$a = \frac{(2.37)(60)}{0.85(8)(18)} = 1.16" \qquad c = \frac{1.16}{0.65} = 1.79"$$

$$\varepsilon_s = \frac{0.003}{1.79}(27 - 1.79) = 0.0423 > 0.00207 \text{ STEEL YEILDS}$$
$$> 0.005 \quad \phi = 0.9$$

$$\phi M_n = 0.9(2.37)(60)\left(27 - \frac{1.16}{2}\right)/12 = 281.8\ 'K > 111.7\ 'K \quad \underline{OK!} \checkmark$$

SPAN 2 – SHEAR

$V_c = 2\sqrt{8000}(18)(27)/1000 = 86.9^K$

$\phi V_n = 0.5(0.75)(86.9) = 32.6^K > 16.3^K$ ∴ NO STEEL REINF. NEEDED.

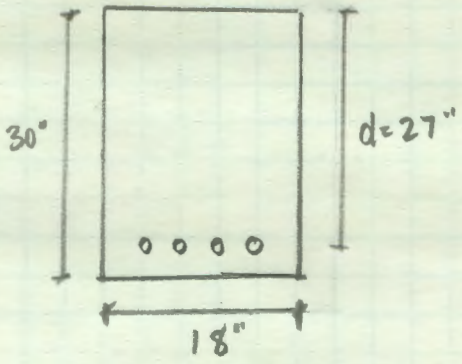
SPAN 3 – FLEXURE

$M_u = 393'^K$
$V_u = 39.8^K$

$A_{s,MIN} = 2.17\ IN^2$
$A_{s,MAX} = 15.3\ IN^2$

→ REQ'D STEEL

$A_s = \frac{393}{4(27)} = 3.64\ IN^2$ ∴ TRY (4) #9's $A_s = 4.00\ IN^2$



→ ASSUME $f_s \geq f_y$

$a = \frac{(4.00)(60)}{0.85(8)(18)} = 1.96"$ $\quad c = \frac{1.96}{0.65} = 3.02"$

$\varepsilon_s = 0.0238 > 0.00207$ ∴ STEEL YIELDS
> 0.005 ∴ $\phi = 0.9$

$\phi M_n = 0.9(4.00)(60)(27 - \frac{1.96}{2})/12 = 476'^K > 393'^K$ OK! ✓

SPAN 3 - SHEAR.

$V_c = 86.9^K$

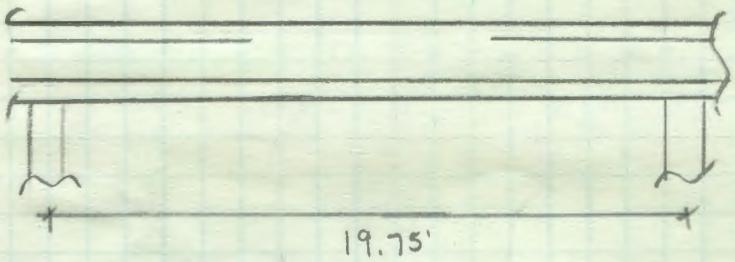
$\phi V_n = 32.6^K$

$V_u @ d = 27' = 39.8 - (6.7)(27/12) = 24.7^K < 32.6^K$

$\therefore$ NO SHEAR REINF. NEEDED.

DEFLECTIONS - SPAN 3 (LARGEST SPAN.)

NOTE: PREVIOUS DESIGN VALUES CALCULATED BY HAND WERE USED FOR SAP2000 VERIFICATION. DEFLECTIONS WILL NOW USE OUTPUT FROM SAP



PROPERTIES

f'_c = 8 KSI
f_y = 66 KSI
A_s = 4 IN^2
A_s' = 4 IN^2
d = 27"
ρ = .4/(18)(27) = 0.0082
E_c 5098 KSI
E_s = 29000 KSI
d' = 3.0"
ρ' = 4/(27)(18) = 0.0082

W_D = 1.61
W_{SD} = 1.75
W_L = 1.60

(+) MOMENTS

M_D^+ =
M_L^+ =
M_{TL}^+ =
M_{SUS}^+ =

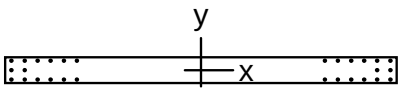
(-) MOMENTS

M_D^- =
M_L^- =
M_{TL}^- =
M_{SUS}^- =

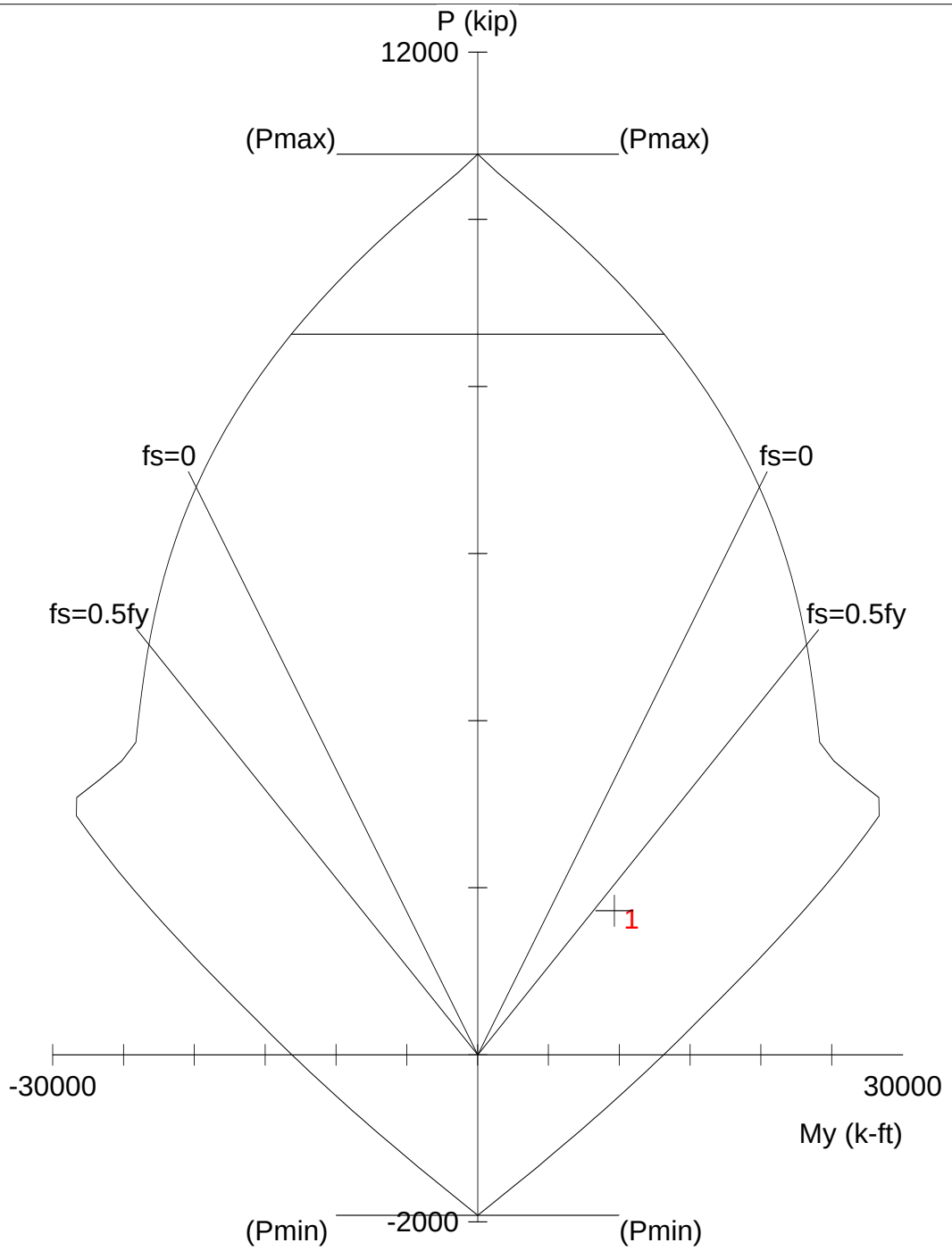
MODULUS OF RUPTURE & MODULAR RATIO

$$f_r = 7.5\sqrt{8000} = 671 \text{ psi}$$

$$n = \frac{E_s}{E_c} = \frac{29000}{5098} = 5.69$$



180 x 12 in



Code: ACI 318-08

Units: English

Run axis: About Y-axis

Run option: Investigation

Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/05/12

Time: 12:25:38

spColumn v4.80. Licensed to: Penn State University. License ID: 58318-1027155-4-22545-2CF68

File: X:\Thesis\spColumn\G7.col

Project: SW G7

Column:

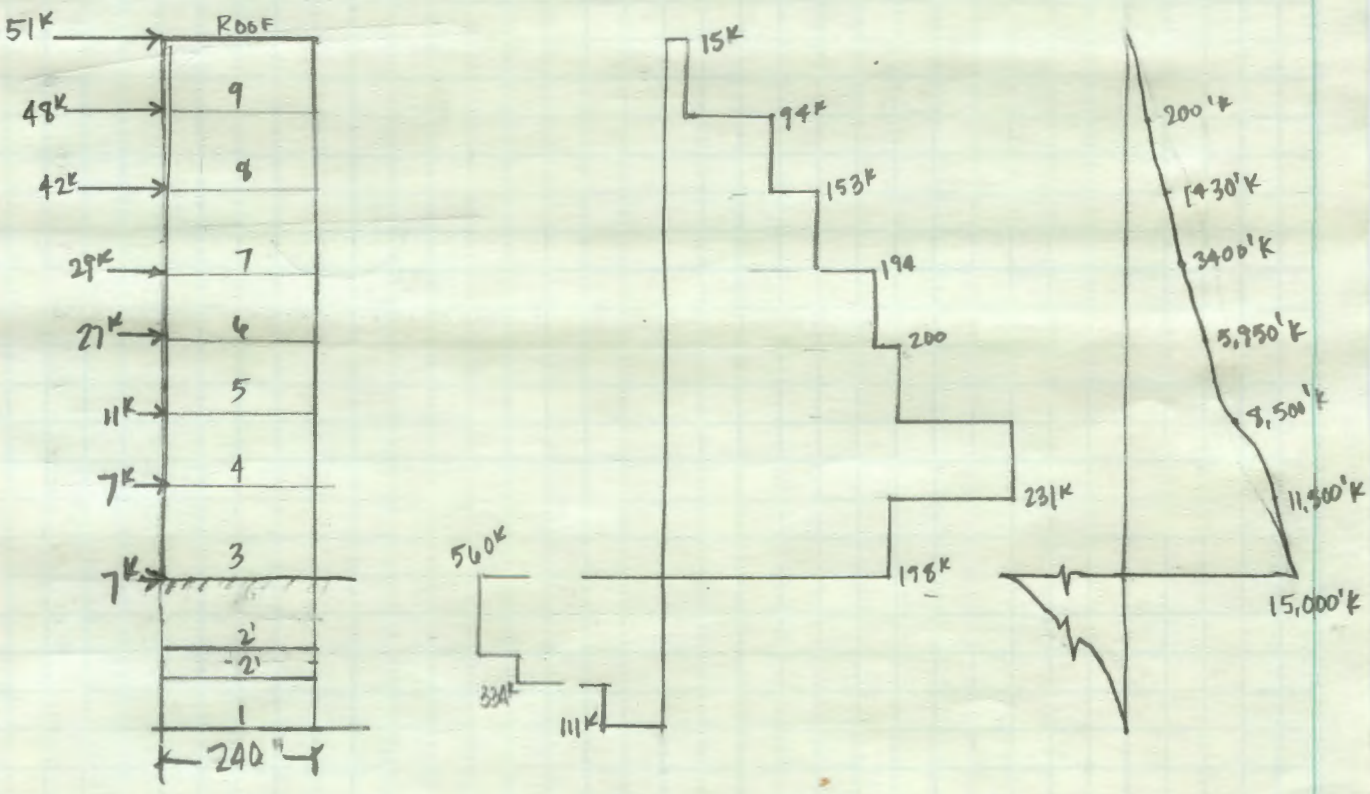
Engineer:

f'c = 8 ksi	fy = 60 ksi	Ag = 2160 in^2	28 #10 bars
Ec = 5098 ksi	Es = 29000 ksi	As = 35.56 in^2	rho = 1.65%
fc = 6.8 ksi		Xo = 0.00 in	Ix = 25920 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 5.832e+006 in^4
Beta1 = 0.65		Min clear spacing = 3.23 in	Clear cover = 0.86 in

Confinement: Tied

phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

DESIGN SHEAR WALL



WALL @ 3

$V_u = 198^K$ $M_u = 15{,}000'^K$ $P_u = 960^K$

→ $h = 12"$ OK?

$$V_u = \phi 10\sqrt{f'_c}\, h d \;;\; d = 0.8\ell \quad (ACI\ 11.7.4)$$

$$= 0.75(10)\sqrt{8000}(12)(0.8)(240) = 1545^K > 198^K \text{ OK! } ✓$$

→ V_c

$$= 3.3\lambda\sqrt{f'_c}\, h d + \frac{N_u d}{4\ell_w} = 3.3\sqrt{8000}(12)(0.8)(240) + \frac{960(0.8)(240)}{4(240)}$$

$$= 680^K$$

$$= \left[0.6\lambda\sqrt{f'_c} + \frac{\ell_w\left(1.25\lambda\sqrt{f'_c} + 0.2N_u/\ell_w h\right)}{\frac{M_u}{V_u} - \frac{\ell_w}{2}}\right] h d$$

$$= \left[0.6\sqrt{8000} + \frac{(240)\left(1.25\sqrt{8000} + 0.2(960)/(240)(12)\right)}{\frac{(15000)12}{198} - \frac{240}{2}}\right](12)(8)(240) = \underline{\underline{202^K}}$$

CONTROLS

→ NEED SHEAR REINF?

$$\frac{\phi V_c}{2} = \frac{0.75(202)}{2} = 76^k < 198^k \quad \text{YES!}$$

→ HORIZONTAL SHEAR REINF

$$V_u = \phi V_c + \phi V_s = \phi V_c + \phi \frac{A_{st} f_y d}{s}$$

$$\frac{A_v}{s} = \frac{(198) - (0.75)(202)}{0.75(60)(0.8)(240)} = 0.0054$$

TRY #4's

$$s = \frac{2(0.2)}{0.0054} = 74"$$

$$s_{MAX} \quad \frac{l_w}{5} = \frac{240}{5} = 48"$$

$$3h = 3(12) = 36"$$

$18" \rightarrow$ CONTROLS

2 LEGS OF #4's @18"

$$\rho = \frac{0.4}{(18)(12)} = 0.0019 < 0.0025 \quad \text{NO GOOD!}$$

$$0.0025 = \frac{0.4}{s(12)} \rightarrow s = 12" \qquad \rho = \frac{0.4}{(12)(12)} = 0.0028 \text{ OK!}$$

VERTICAL SHEAR REINF.

$$\rho_{MIN} = 0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right)(\rho_h - 0.0025)$$

$$= 0.0025 + 0.5\left(2.5 - \frac{(12)(19)}{(12)(20)}\right)(0.0028 - 0.0025) = 0.00273$$

TRY #4 CLOSED VERT BARS (2 LEGS)

$$s = \frac{2(0.2)}{12(0.00273)} = 12.2" \rightarrow \text{USE } 12"$$

$$s_{MAX} = 18"$$

USE (2) LEGS OF #4's @12" FOR VERTICAL & HORIZ. REINFORCEMENT

→ FLEXURAL REINFORCING

$M_u = 15000'k$

$$A_{s.req} \approx \frac{M_u}{4d} = \frac{15000}{4(0.8)(240)} = 19.5\ in^2$$

$$A_{s\,min} = \frac{3\sqrt{f'_c}\,bd}{f_y} = \frac{3\sqrt{8000}(12)(0.8)(240)}{60000} = 10.3\ in^2$$

$$\frac{200\,bd}{f_y} = \frac{200(12)(0.8)(240)}{60000} = 7.68\ in^2$$

$$A_s = \rho_{max}\,bd \;;\; \rho_{max} = 0.85(0.65)\left(\frac{4}{60}\right)\left(\frac{0.003}{0.007}\right) = 0.0318$$

$$= (0.0318)(12)(0.8)(240) = 72.7\ in^2$$

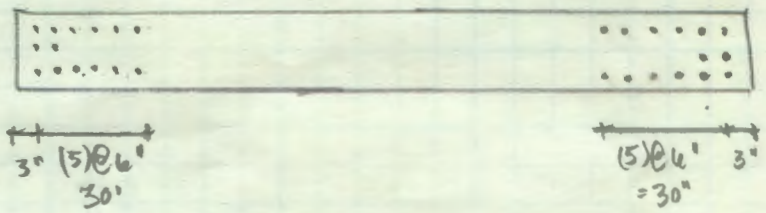
USE (14) #10's @ EACH END $A_s = 17.78\ in^2$

ASSUME $f_s \geq f_y$

$$a = \frac{(17.78)(60)}{0.85(8)(12)} = 13.1 \qquad c = \frac{13.1}{0.65} = 20.1"$$

$$\varepsilon_s = \frac{0.003}{20.1}(192 - 20.1) = 0.024 > 0.00207 \quad \text{STEEL YEILDS}$$
$$> 0.005 \quad \phi = 0.9$$

$$\phi M_n = 0.9(17.78)(60)\left[196 - \frac{13.1}{2}\right]/12 = 15,158'k > 15,000'k$$



SEE Sp COLUMN.

BOUNDARY ELEMENT REINF.

$\frac{400}{f_y} = \frac{400}{60000} = 0.0066$ (ACI 21.9.6.5)

$\rho_{@3} = \frac{17.78}{12(6)(6)} = 0.0412 > 0.0066$ ∴ USE BOUNDARY TIES.

$X = MAX \quad \frac{c}{2} = \frac{20.1}{2} = 10.1"$

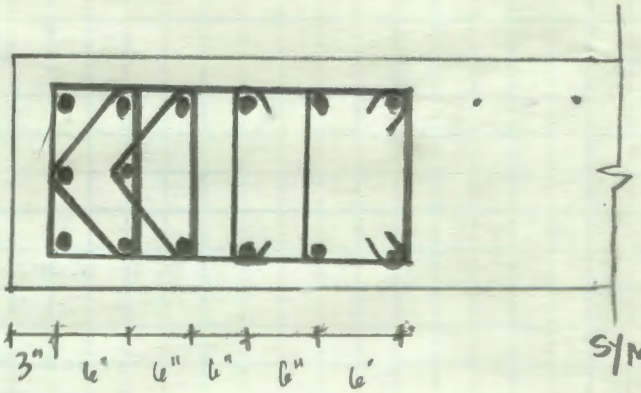
$C - 0.1 l_w = 20.1 - (0.1)(180) = 2.1"$

USE TOTAL 30" OF #10's

TRY SPACING @ 4"

$A_{SH} = 0.09(4)(30")\left(\frac{8}{60}\right) = 1.44\ in^2$ USE (5) #5's @ 4" O.C.

(ACI 21.6.4.4)



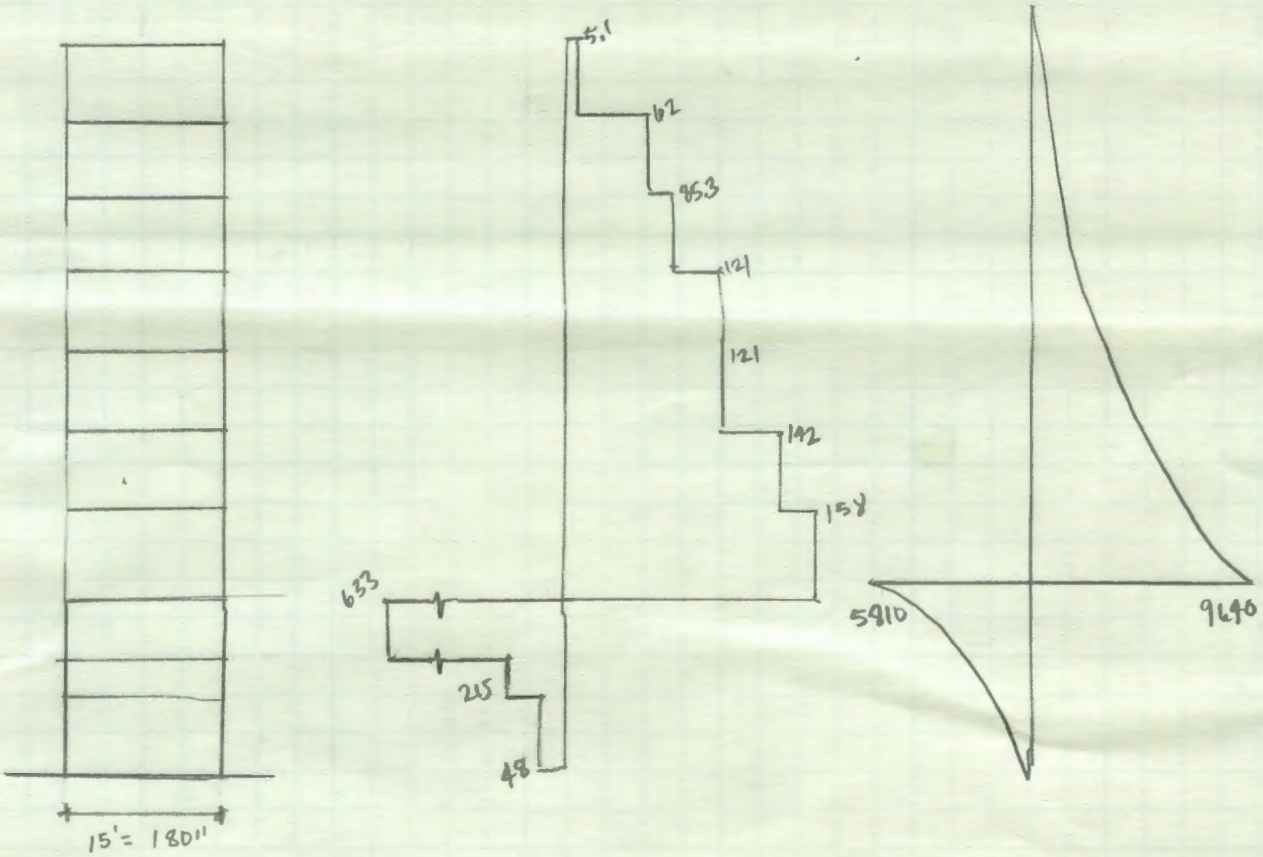
SPLICING

$l_d = \frac{3}{40}\frac{f_y}{\lambda\sqrt{f'_c}} \cdot \left[\frac{\psi_t \psi_e \psi_s}{\frac{c_b + K_{tr}}{d_b}}\right]$ ASSUME $K_{tr} = 0$

$= \frac{3}{40} \cdot \frac{60000}{\sqrt{8000}} \cdot \frac{(1)}{(1.5 + 1.27/2)} = 23.6\, d_b = 23.6(1.27) = 30"$

USE CLASS B SPLICE $= 1.3(30") = 39" = 3'-3"$

DESIGN SHEAR WALL G7 (Y-DIRECTION)



WALL @ 3

$V_u = 158^K$
$M_u = 9640'^K$
$P_u = 1740^K$

$d = .8(180) = 144"$

h = 12" OK?

$$V_c = \phi 10\sqrt{f'_c}\, hd = (0.75)(10)\sqrt{8000}(12)(0.8)(180) = 1159^K > 158^K$$

V_c

$$= 3.3\lambda\sqrt{f'_c}\, hd + \frac{N_u d}{4l_w} = 3.3\sqrt{8000}(12)(144) + \frac{1740(144)}{4(180)} = \underline{510.4^K}$$

$$= \left[0.6\sqrt{f'_c} + l_w\frac{1.25\sqrt{f'_c} + 0.2N_u/l_w h}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right]hd = \left[0.6\sqrt{8000} + \frac{180(1.25)\sqrt{8000} + 0.2(1740)/180(12)}{\frac{9460(12)}{158} - \frac{180}{2}}\right](12)(144)$$

$$= \underline{145^k}$$

NEED SHEAR REINF?

$$\frac{\phi V_c}{2} = \frac{0.75(145)}{2} = 54.4^k < 158^k \quad \text{YES!}$$

HORIZ. REINF

$$V_u = \phi V_c + \phi V_s = \phi V_c + \phi \frac{A_v f_y d}{s}$$

$$\frac{A_v}{s} = \frac{158 - (0.75)(145)}{0.75(60)(144)} = 0.0076$$

TRY 2 #4's

$$s = \frac{(2)(0.2)}{0.0076} = 52"$$

$$s_{MAX} = \frac{l_w}{5} = \frac{180}{5} = 36"$$

$$3h = 3(12) = 36"$$

$18" \rightarrow$ CONTROLS

$$\rho = \frac{0.4}{12(18)} = 0.0019 < 0.0025 \quad \text{X No Good.}$$

TRY 2 #4's @ 12"

$$\rho = \frac{0.4}{12(12)} = 0.0028 > 0.0025 \quad \text{OK!} \checkmark$$

VERT. REINF.

$$\rho_{MIN} = 0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right)(\rho_h - 0.0025)$$

$$= 0.0025 + 0.5\left(2.5 - \frac{12}{140}\right)(0.0028 - 0.0025) = 0.002865$$

TRY (2) #4

$$s = \frac{0.4}{12(0.002865)} = 11.6 \rightarrow \text{TRY } 10" \quad \rho_v = 0.0033$$

$s_{MAX} = 18"$ OK! ✓

HORZ. REINF (2) #4 @ 12"

VERT. REINF. (2) #4 @ 12"

→ FLEXURAL REINF.

$M_u = 9640$ 'k

$P_u = 1740^K$

$A_s \approx \frac{M_u}{3d} = \frac{9640}{3(144)} = 22.3\ in^2$

$A_{s,min} = \frac{3\sqrt{f'_c}\,hd}{f_y} = \frac{3\sqrt{8000}\,(12X144)}{60000} = 7.7\ in^2$

$= \frac{200\,hd}{f_y} = \frac{200(12)(144)}{60000} = 5.76\ in^2$

$A_{s,max} = \rho hd$; $\rho_{max} = 0.85(0.65)\frac{\beta_1 @ 8ksi}{60}\left(\frac{0.003}{0.007}\right) = 0.0316$

$= (0.0316)(12)(144) = 54.6\ in^2$

TRY (14) #10's $A_s = 17.78\ in^2$

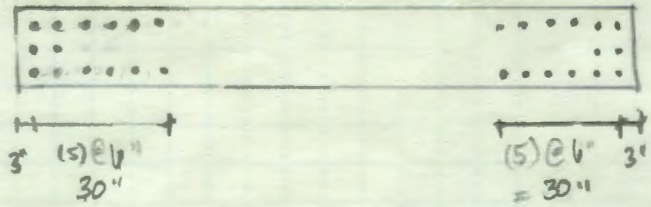
ASSUME $f_s \geq f_y$

$a = \frac{(17.78)(60)}{0.85(9)(12)} = 13.1$ $\quad c = \frac{13.1}{0.65} = 20.1$

$\varepsilon_s = \frac{0.003}{20.1}(144 - 20.1) = 0.0185 > 0.00207$ STEEL YEILDS

> 0.005 $\phi = 0.9$

$\phi M_n = 0.9(17.78)(60)\left(144 - \frac{13.1}{2}\right)/12 = 11{,}010$ 'k $>$ 9640 'k OK! ✓



SEE Sp COL

BOUNDARY ELEMENTS @ LVL 3

$$\frac{400}{f_y} = \frac{400}{60000} = 0.0066 \qquad \text{(ACI 21.7.6.5)}$$

$A = 12(180) = 2160\ IN^2$ $\qquad P = 1740^K$

$S = \frac{12(180)^2}{6} = 64800\ IN^3$ $\qquad M_u = 9640'K = 115,680\ IN\text{-}K$

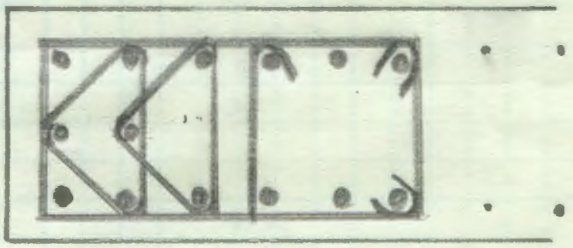
$$f_c = \frac{1740}{2160} + \frac{115,680}{64800} = 2.6\ KSI = 32.5\%\ OF\ f'c = 8000\ PSI$$
$$> 0.2 f'c$$

$\therefore$ BOUNDARY ELEMENT NEEDED.

USE FULL 30" OF (19) #10's @ S = 4"

$$A_{SH} = 0.09(4)(30)\left(\frac{8}{60}\right) = 1.44\ IN^2 \qquad \text{(ACI 21.6.4.4)}$$

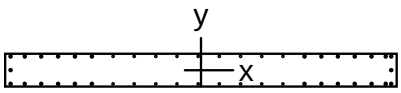
USE (5) #5's $A_s = 1.55\ IN^2$



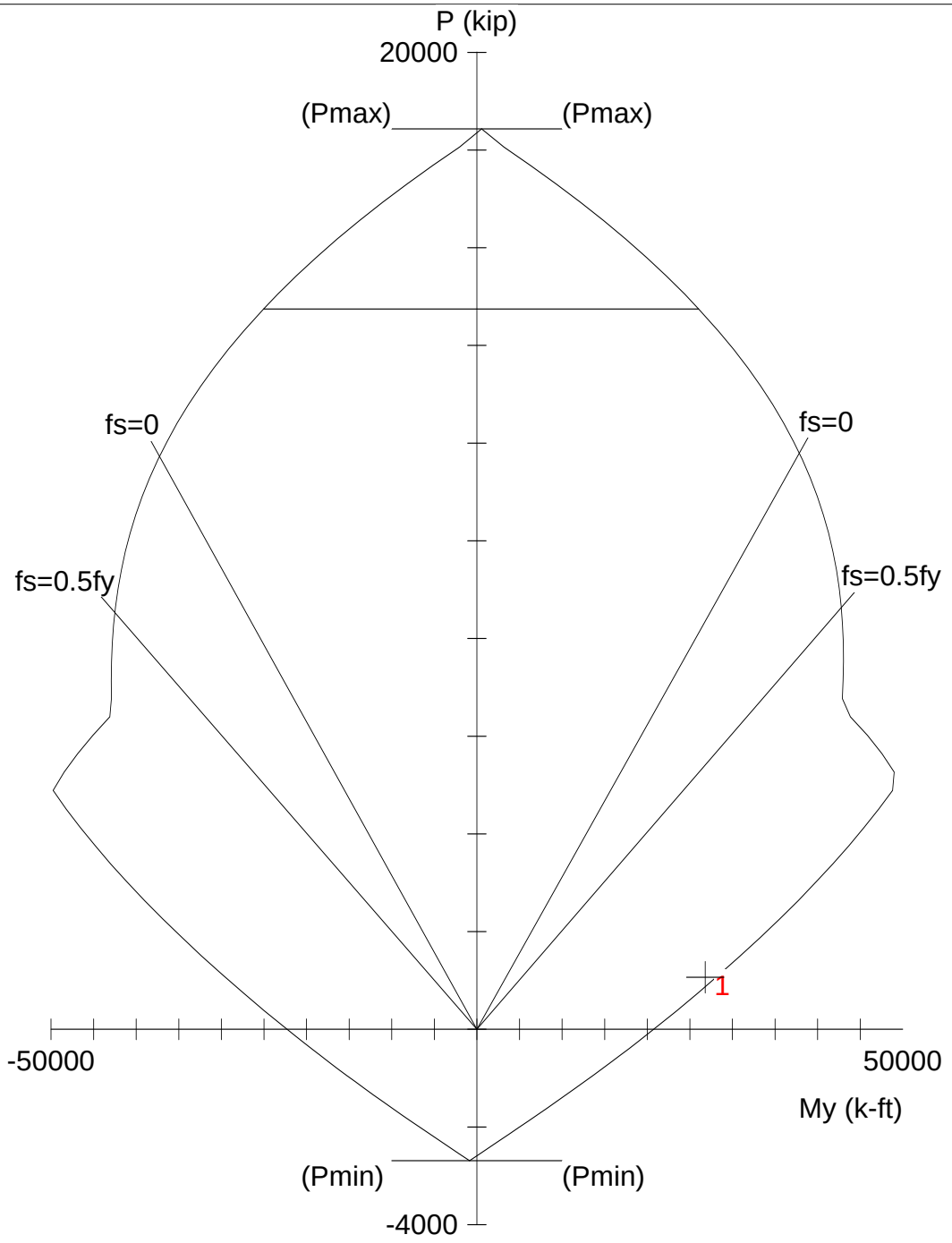
SPLICING

$$l_d = \frac{3}{40}\left(\frac{60000}{\sqrt{8000}}\right)\left(\frac{1}{1.5 + \frac{1.27}{2}}\right) \qquad \text{ASSUME } K_{TR} = 0 \qquad = 30"$$

CLASS B SPLICE = $1.3(30) = 39" = 3'-3"$



210 x 18 in



Code: ACI 318-08

Units: English

Run axis: About Y-axis

Run option: Investigation

Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/05/12

Time: 12:24:19

spColumn v4.80. Licensed to: Penn State University. License ID: 58318-1027155-4-22545-2CF68

File: X:\Thesis\Shear Wall GO X - Dir.col

Project: Shear Wall GD X-Dir

Column: GD

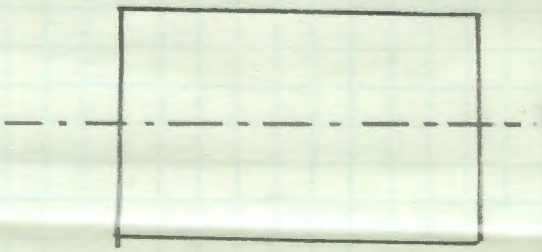
Engineer:

f'c = 8 ksi	fy = 60 ksi	Ag = 3780 in^2	46 bars
Ec = 5098 ksi	Es = 29000 ksi	As = 49.78 in^2	rho = 1.32%
fc = 6.8 ksi		Xo = 0.00 in	Ix = 102060 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 1.38915e+007 in^4
Beta1 = 0.65		Min clear spacing = 1.73 in	Clear cover = 0.86 in

Confinement: Tied

phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

DESIGN COLUMN G9 IN MOMENT FRAME GC



$f'_c = 6{,}000$ psi

$f_y = 60000$ psi

@ LEVEL 3

$V_u = 8.1^K$
$M_u = 250'^K$
$P_u = 943^K$

→ GROSS AREA (TARGET REINFORCEMENT = 3.0%.)

$$A_g \geq \frac{P_u}{0.4(f'_c + f_y \rho_g)} = \frac{943}{0.4(6 + 60(3\%))} = 30.2 \text{ IN}^2$$

TRY $18" \times 24" = 432 \text{ IN}^2$

← ECCENTRICITY

$$e = \frac{M_u}{P_u} = \frac{250(12)}{943} = 3.2" \Rightarrow \frac{e}{h} = \frac{3.2}{18} = 0.178$$

$$\gamma = \frac{18 - (2)(2.5)}{18} = 0.722 \rightarrow \text{INTERPOLATE B/W } 0.6 \text{ \& } 0.75$$

FIG. 11a $\phi = 0.6$

$$\frac{\phi P_n}{bh} = \frac{943}{(24)(18)} = 2.61 \qquad \frac{\phi M_n}{30(12)^2} = \frac{250(12)}{30(12)^2} = 0.69$$

REQUIRES > 5.0%.

FIG. 11b

$$\frac{\phi P_n}{bh} = 2.61 \qquad \frac{\phi M_n}{bh^2} = 0.69$$

REQUIRES 4%.

$$\left[\frac{0.75-0.722}{0.75-0.6}\right](5-4)+4 = 4.12\ \%$$

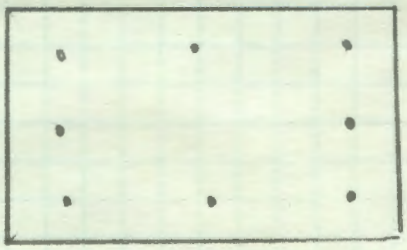
$A_s = 0.412(18)(24) = 18.1\ IN^2$ $\quad d = 21.5"$

$$A_{s.MIN} = \frac{3\sqrt{6000}\,(18)(21.5)}{60000} = 1.49\ IN^2$$

$$\rho_{MAX} = 0.85(0.65)\frac{b}{60}\left(\frac{0.003}{0.007}\right) = 0.0237$$

$A_{SMAX} = 0.0237(18)(21.5) = 9.16\ IN^2$

TRY (8) # 8's $= 6.32\ IN^2$



SPLICING

$l_d = 38.7"$ (SAME AS LAST DESIGN)

$L = \underline{\underline{50.3"}}$

TIES

MIN = $16d_b = 16(1) = 16"$ → CONTROLS

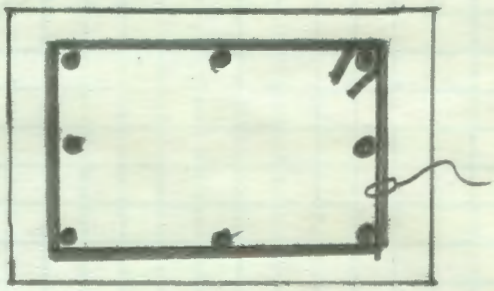
$18" = 18"$

SHEAR

$V_u = 8.1^K$

$V_c = 2\left[1 + \frac{943}{2000(14)(24)}\right]\sqrt{4000}(18)(21.5) = 47^K$

$47^K > 8.1^K \rightarrow$ NO SHEAR REINF NEEDED



(8) #9"

#3 STIRRUPS @ 16" O.C.

ASSUME $f_s \geq f_y$

$a = \frac{6.32(60)}{0.85(6)(18)} = 4.13$ $\quad c = \frac{4.13}{0.75} = 5.51$

$\varepsilon_s = \frac{0.003}{5.51}(21.5 - 5.51) = 0.009 > 0.00207$ STL. YIELDS

> 0.005 $\phi = 0.9$

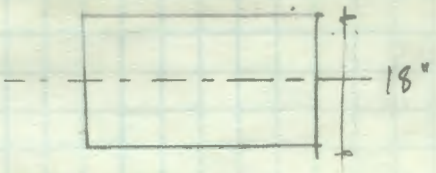
$\phi M_n = 0.9(6.32)(60)(21.5 - \frac{4.13}{2})/12 = 552'^K > 306'^K$ OK! ✓

SEE spCOLUMN FOR INTERACTION DIAGRAM.

DESIGN CONCRETE MOMENT FRAME COL. G7/G1 @ LVL3

$P_u = 926^k$

$M_u = 306'^k$



TARGET REINFORCEMENT → 3%

$e = \frac{306(12)}{926} = 3.97"$

$\frac{e}{h} = \frac{3.97"}{18"} = 0.22$

$\gamma = \frac{18 - (2)(2.5)}{18} = 0.722$ - INTERPOLATE B/W FIG. 11a-11b

FIG. 11a $\gamma = 0.6$

$\rho = 3\%$ $\frac{e}{h} = 0.22$ $\frac{\phi P_n}{b \cdot h} = 2.35$

FIG. 11b $\gamma = 0.75$

$\rho = 3\%$ $\frac{e}{h} = 0.22$ $\frac{\phi P_n}{b \cdot h} = 2.5$

$\left(\frac{0.722 - 0.6}{0.75 - 0.6}\right)(2.5 - 2.35) + 2.35 = 2.47$

b ESTIMATE

$\frac{\phi P_n}{b \cdot h} = 2.47 = \frac{926}{b \cdot 18} \rightarrow b = 20.8" \Rightarrow$ USE 24"

FIG. 11a

$\frac{\phi P_n}{bh} = \frac{926}{(19)(24)} = 2.15$ $\frac{\phi M_n}{bh^2} = \frac{306(12)}{(18)(24)^2} = 0.35$

$\rho = 1.0\%$

FIG. 11b

$\frac{\phi P_n}{bh} = 2.15$ $\frac{\phi M_n}{bh^2} = 0.03$

$\rho = 1.0\%$

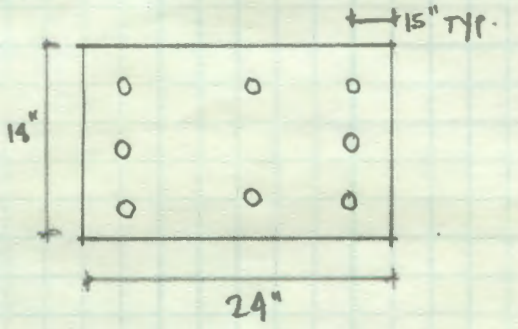
AREA STEEL

$A_{s_1} = 0.01(18)(24) = 4.32 \text{ IN}^2$

$A_{SMIN} = \dfrac{3\sqrt{6000}\,(18)(22.5)}{60000} = 1.57 \text{ IN}^2$

$A_{SMAX} = (0.0236)(18)(22.5) = 9.56 \text{ IN}^2$

USE (8) # 8's $A_S = 6.32 \text{ IN}^2$



SEE SPCOLUMN INTERACTION DIAGRAM.

SPLICING.

- ASSUME ALL REBAR IS SPLICED @ SAME LOCATION.

$$l_d = \left(\frac{f_y \psi_t \psi_b}{20\lambda\sqrt{f'_c}}\right) d_b = \left(\frac{(60000)(1.0)(1.0)}{20\sqrt{6000}}\right) 1.00 = 38.7"$$

$L = 1.3(38.7) = 50.3"$

TIES

MIN = $16(1.00") = 16"$ → CONTROLS.

$48(3/8") = 18"$

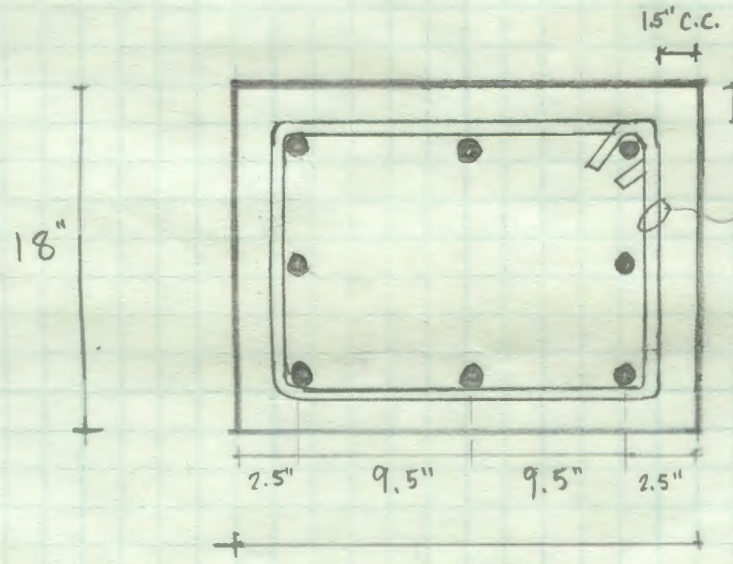
SHEAR.

$V_u = 3.3^K$

$V_c = 2\left[1 + \frac{926}{2000(15)(24)}\right]\sqrt{4000}(18)(22.5) = 129^K$

$\phi .5V_c = 48.7^K > 3.3^K$ OK! ✓

FINAL DESIGN.



$d = 24" - 1.5 - \frac{3}{8}" - 0.5"$
$= 21.625" = \text{USE } 21.5"$

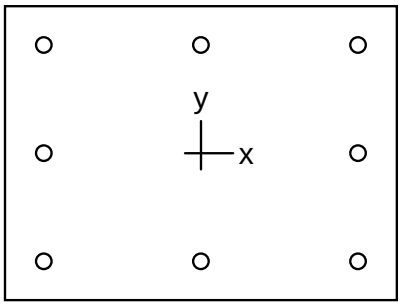
ASSUME $f_s \geq f_y$

$a = \frac{6.32(60)}{0.85(6)(18)} = 4.13"$ $\quad c = \frac{4.13}{.75} = 5.51"$

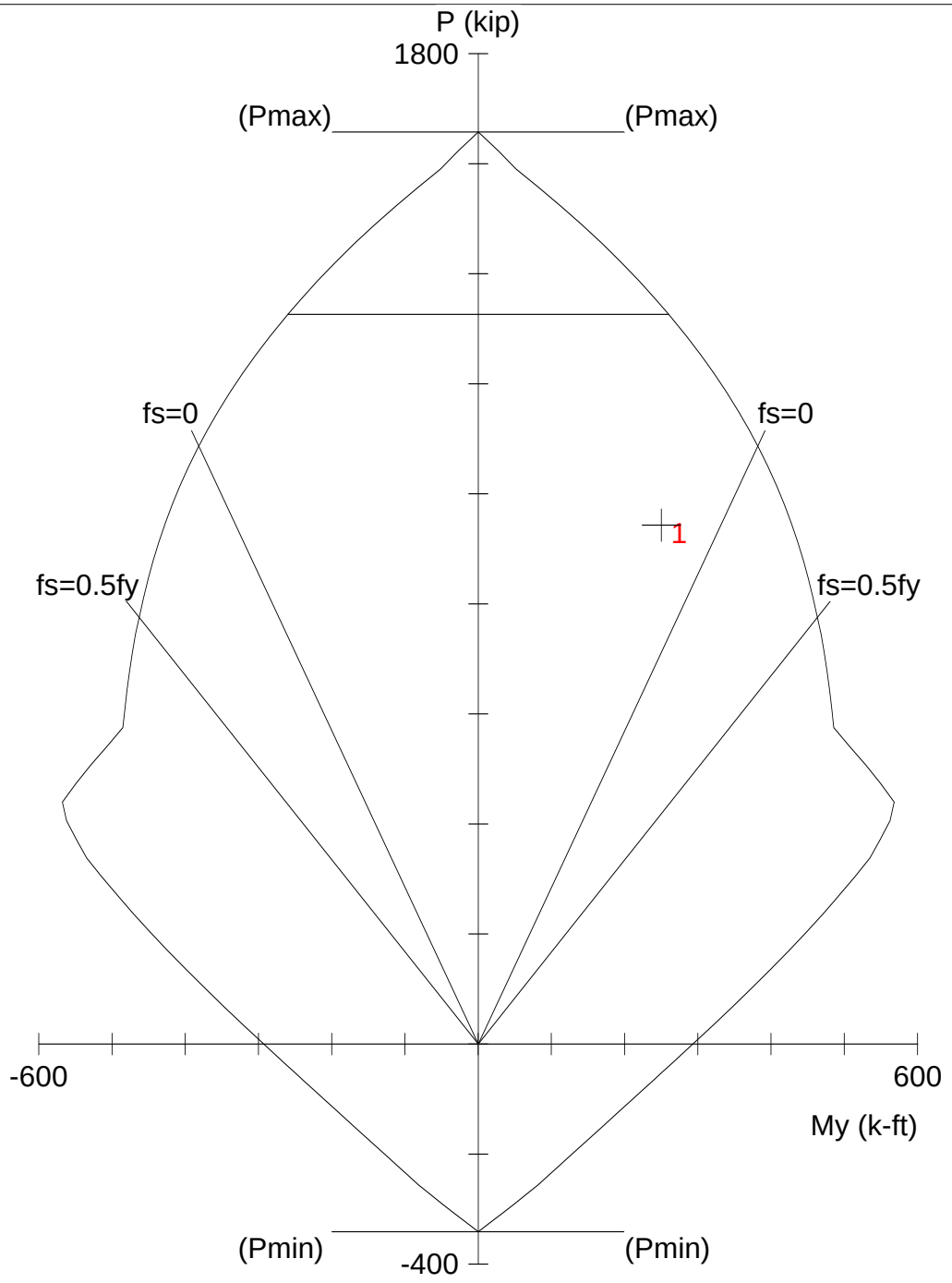
$\varepsilon_s = \frac{0.003}{5.51}(21.5 - 5.51) = 0.008 > 0.00207$ STEEL YEILDS
$> 0.005 \therefore \phi = 0.9$

$\phi M_n = 0.9(6.32)(60)(21.5 - \frac{4.13}{2})/12 = 552'^K > 250'^K$ OK! ✓

SEE SpCOLUMN FOR INTERACTION DIAGRAM.



24 x 18 in



Code: ACI 318-08

Units: English

Run axis: About Y-axis

Run option: Design

Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/05/12

Time: 12:23:41

spColumn v4.80. Licensed to: Penn State University. License ID: 58318-1027155-4-22545-2CF68

File: X:\Thesis\spColumn\GCG9.col

Project: G9GC

Column:

Engineer:

f'c = 6 ksi	fy = 60 ksi	Ag = 432 in^2	8 #8 bars
Ec = 4415 ksi	Es = 29000 ksi	As = 6.32 in^2	rho = 1.46%
fc = 5.1 ksi		Xo = 0.00 in	Ix = 11664 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 20736 in^4
Beta1 = 0.75		Min clear spacing = 5.63 in	Clear cover = 1.88 in

Confinement: Tied

phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65