ENGINEERING VENTURES INC

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85 Mechanic Street, Suite 350A, Lebanon, NH 03766 · Tel: 603-442-9333 · Fax: 603-442-9331
18 Division Street, Saratoga Springs, NY 12866 · Tel: 518-224-0004

Design Calculations

For:

VT Route 17 (Bridge #2) Culvert Replacement

Addison, VT

For:

S.D. Ireland

Submitted On:

September 18, 2013

For Approval

STATE OF VERMONT
DAVID W. BOEHM
No. 3581
REGISTERED
PROFESSIONAL ENGINEER

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BASIS OF DESIGN

Referenced Drawings and Documents:

- State of Vermont Agency of Transportation Town of Addison, County of Addison, Vermont Route 17, Bridge Number #2 Drawings; dated March 11, 2013

Referenced Codes:

- AASHTO LRFD Bridge Design Specifications 2010; Fifth Edition
- State of Vermont, Agency of Transportation Design Manual 2010

Loading Required:

- Traffic: HL-93

General Design Parameters:

- $\gamma_{soil} = 140$ pcf
- $\gamma_{concrete} = 150$ pcf
- $\varphi = 32°$ *
- $K_A = \tan^2(45° - \varphi/2) = 0.307$
- $K_P = \tan^2(45° + \varphi/2) = 3.25$
- $K_0 = 1 - \sin(\varphi) = 0.47$
- Factored bearing resistance = 3015 psf
- f'_c – 6 ksi
- $f_y = 60$ ksi
- Reinforcing Tolerances: +/- 1" Spacing, +/- ¼" Clearance
- 2" reinforcement cover, unless noted otherwise
- General Load Combination Factors: (AASHTO 3.22)
    - DL = 1.25/0.9
    - EL = 1.35/1.0
    - LL = 1.75

* Soil assumption assumed and to be verified by EOR.

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Basis of Design – Culvert:

Loads:

Box Culvert:

Vertical Earth Load (at top of box) = (depth of fill = 3')(140 pcf) = 420 psf
Lateral Earth Load (at top of box) = 0.47(3')(140 pcf) = 197 psf
Lateral Earth Load (at base of box) = 0.47(3'+ 8.83')(140 pcf) = 778 psf

Dead Load = self weight

Box Culvert End:

Lateral Earth Load (at top of box end) = 0.47(1')(140 pcf) = 66 psf
Lateral Earth Load (at base of box end) = 0.47(9')(140 pcf) = 593 psf

Dead Load = self weight
Weight of Headwall = (1.5 ft)(150 pcf) = 225 psf

Live Loads:
Lane Load = .064 ksf
AASHTO HL-93 Truck – 8 k and 32 k axle loads, 14 ft apart*
AASHTO HL-93 Tandem – (2) 24 k axle loads 4 ft apart*

*Loads applied to maximize stresses for design

Additional Factors:

Multipresence Factor, m = 1.2 (AASHTO 3.6.1.1.2)
$IM = 33(1.0-0.125D_E) \geq 0\% \rightarrow 33(1.0-0.125(3')) = 20.625 > 0\%$
IM = 1.21
(AASHTO 3.6.2.2)

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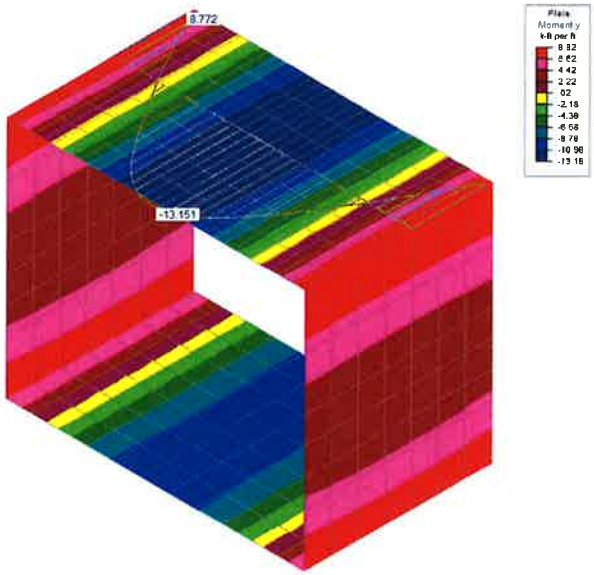
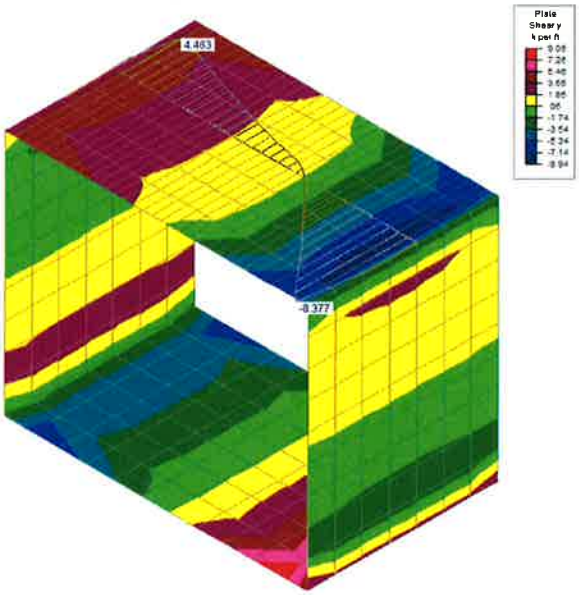
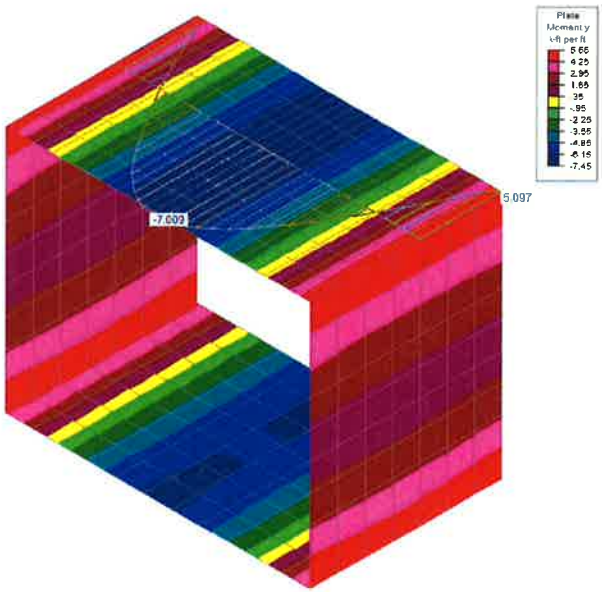
Top Slab Results:



Maximum Moment Load Combination
(Strength 1):
$+M_u = 8.77$ k-ft/ft
$-M_u = -13.15$ k-ft/f



Maximum Shear Load Combination
(Strength 1):
$+V_u = 4.46$ k/ft
$-V_u = -8.38$ k/ft



Maximum Moment Load Combination
(Service 1):
$+M_u = 5.10$ k-ft/ft
$-M_u = -7.01$ k-ft/ft

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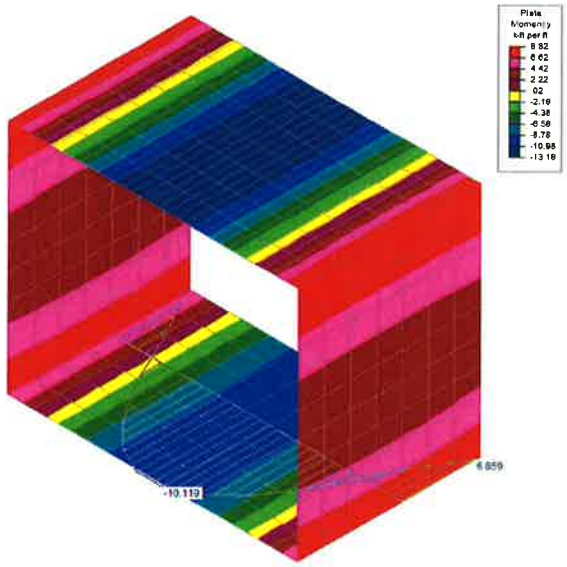
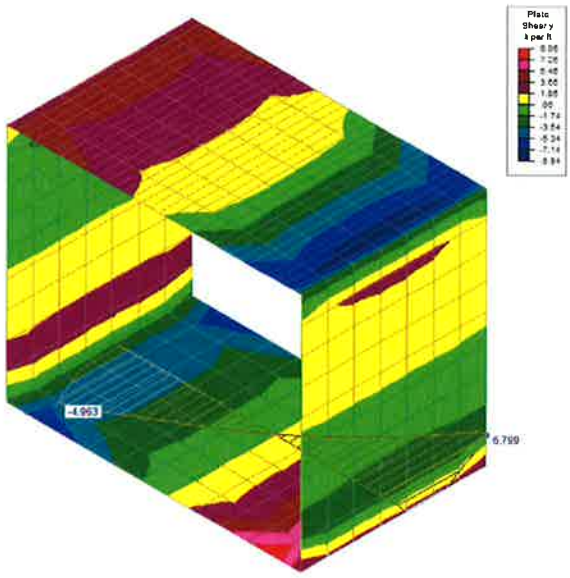
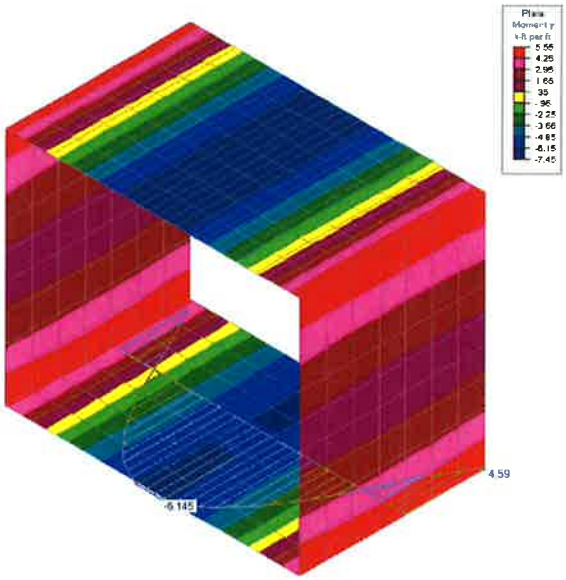
Bottom Slab Results:



Maximum Moment Load Combination
(Strength 1):
$+M_u = 6.86$ k-ft/ft
$-M_u = -10.12$ k-ft/f



Maximum Shear Load Combination
(Strength 1):
$+V_u = 6.80$ k/ft
$-V_u = -4.96$ k/ft



Maximum Moment Load Combination
(Service 1):
$+M_u = 4.59$ k-ft/ft
$-M_u = -6.15$ k-ft/ft

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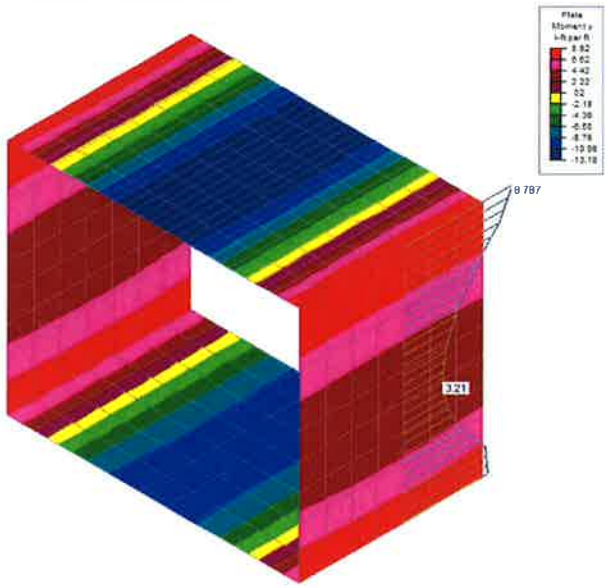
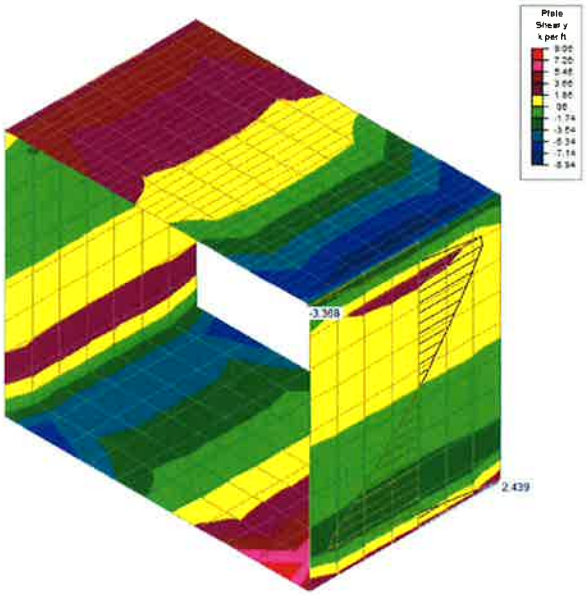
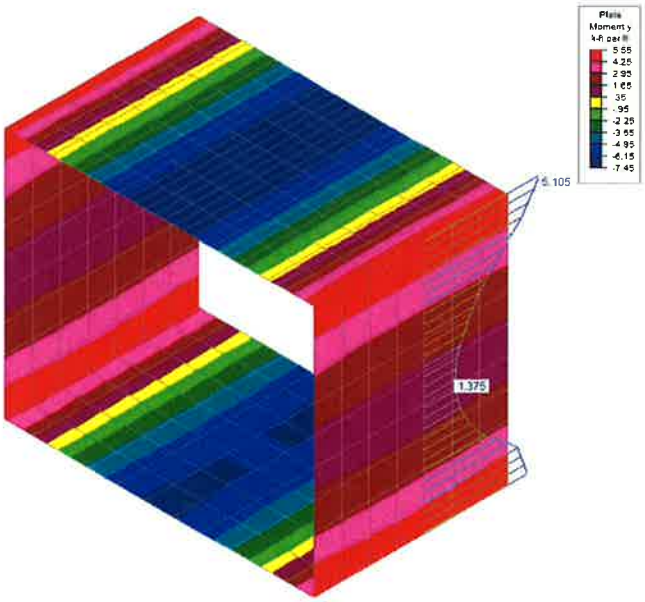
Wall Slab Results:



Maximum Moment Load Combination
(Strength 1):
$+M_u = 8.79$ k-ft/ft
$-M_u = 3.21$ k-ft/f



Maximum Shear Load Combination
(Strength 1):
$+V_u = 2.44$ k/ft
$-V_u = -3.37$ k/ft



Maximum Moment Load Combination
(Service 1):
$+M_u = 5.11$ k-ft/ft
$-M_u = 1.38$ k-ft/ft

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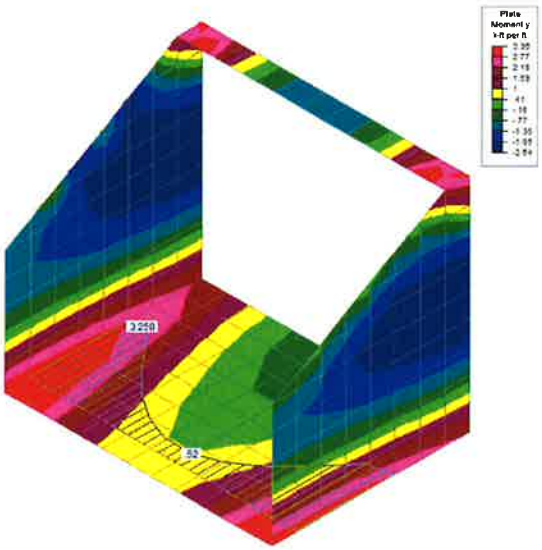
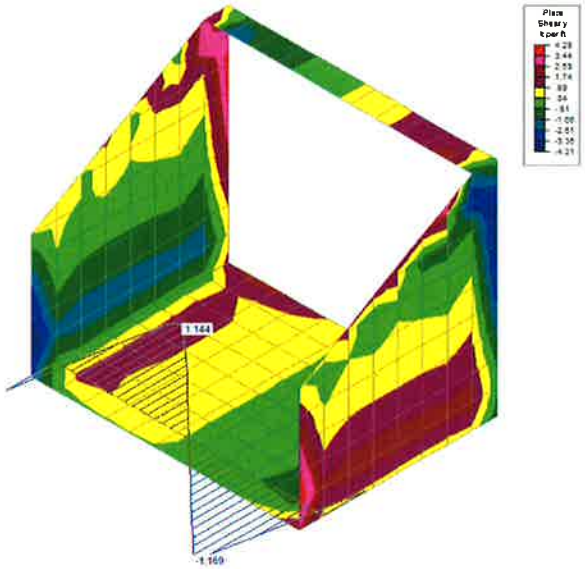
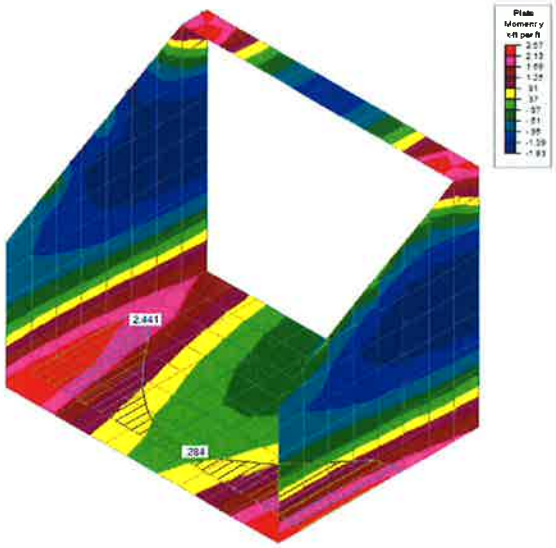
Bottom Slab Results:



Maximum Moment Load Combination
(Strength 1):
$+M_u = 3.26$ k-ft/ft
$-M_u = -1.94$ k-ft/f



Maximum Shear Load Combination
(Strength 1):
$+V_u = 1.98$ k/ft
$-V_u = -1.17$ k/ft



Maximum Moment Load Combination
(Service 1):
$+M_u = 2.44$ k-ft/ft
$-M_u = -1.39$ k-ft/ft

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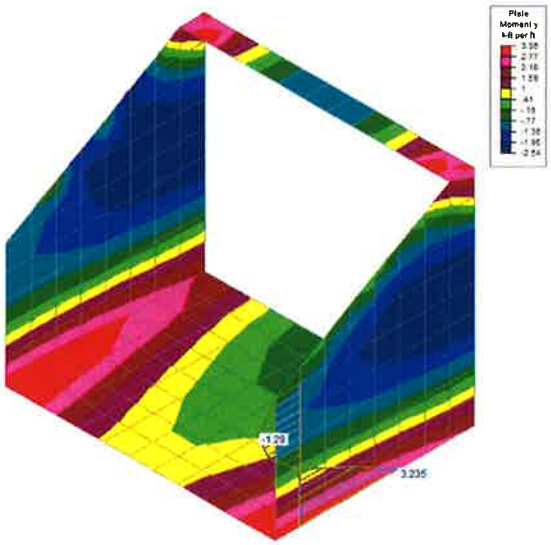
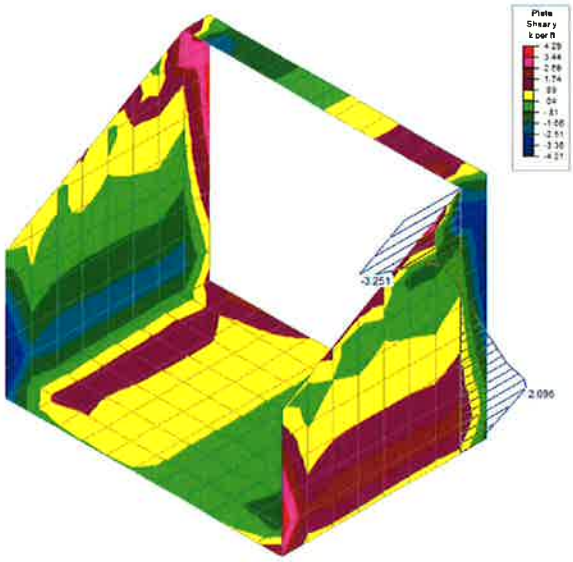
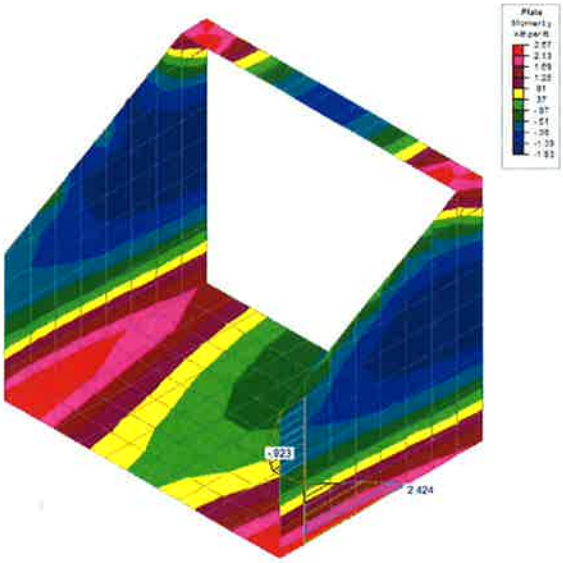


Maximum Moment Load Combination
(Strength 1):
$+M_u = 3.24$ k-ft/ft
$-M_u = -2.498$ k-ft/f



Maximum Shear Load Combination
(Strength 1):
$+V_u = 2.10$ k/ft
$-V_u = -3.25$ k/ft



Maximum Moment Load Combination
(Service 1):
$+M_u = 2.42$ k-ft/ft
$-M_u = -1.79$ k-ft/ft

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Flexural Design

Box Culvert:

Top Slab: M_u = -13.15 k-ft/ft

Minimum Flexural (AASHTO 5.7.3.3.2)

1.33 M_u
1.33(M_u) = 1.33(13.15 k-ft/ft) = **17.5 k-ft/ft – Controls**

-or-

1.2M_{cr}
$I_g = bd^3/12 = (12\text{ in})(10\text{ in})^3/12 = 1000\text{ in}^4$
$S_g = bd^2/6 = (12\text{ in})(10\text{ in})^2/6 = 200\text{ in}^3$
$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6}\text{ ksi}) = .906\text{ ksi}$
$1.2M_{cr} = 1.2(S_g)(f_r) = 1.2(200\text{ in}^3)(.906\text{ ksi}) = 217\text{ k-in} = 18.1\text{ k-ft} > 17.5\text{ k-ft/ft}$

Try #6 at 10 in spacing

$A_s = .528\text{ in}^2$
$T = C = A_s*f_y = (.528\text{ in}^2)(60\text{ ksi}) = 31.7\text{ k}$
$a = A_s*f_y/(.85*f'_c*b) = (31.7\text{ k})/(.85*6\text{ ksi}*12\text{ in}) = 0.52\text{ in}$
$d = 10\text{ in} – 2\text{ in} - .75\text{ in}/2 = 7.625\text{ in}$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s*f_y(d-a/2) = (0.90)(0.528\text{ in}^2)(60\text{ ksi})(7.625\text{ in} - (.52\text{ in}/2)) = 210\text{ k-in} = 17.5\text{ k-ft/ft} =$
17.5 k-ft/ft – NG

Try #6 at 8 in spacing

$A_s = .66\text{ in}^2$
$T = C = A_s*f_y = (.66\text{ in}^2)(60\text{ ksi}) = 39.6\text{ k}$
$a = A_s*f_y/(.85*f'_c*b) = (39.6\text{ k})/(.85*6\text{ ksi}*12\text{ in}) = 0.65\text{ in}$
$d = 10\text{ in} – 2\text{ in} - .75\text{ in}/2 = 7.625\text{ in}$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s*f_y(d-a/2) = (0.90)(0.66\text{ in}^2)(60\text{ ksi})(7.625\text{ in} - (.65\text{ in}/2)) = 260\text{ k-in} =$ **21.7 k-ft/ft >**
17.5 k-ft/ft – OK

Crack Control (AASHTO 5.7.3.4)

$\gamma_e = 0.75$ (Class 2)
$A_s = .66\ in^2$
$f_{ss} = [M_u/(d-(a/2))]/A_s = [7.01\ k\text{-}ft/ft(12\ in/ft)\ /(7.625\ in - (.65\ in/2))]/0.66\ in^2 = 17.6\ ksi$
$d_c = 2\ in + .75/2 = 2.375\ in$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.375\ in/(0.7(10\ in - 2.375\ in)) = 1.44$
$S \leq (700*\gamma_e)/(\beta*\ f_{ss}) - 2d_c = (700*0.75)/(1.44*17.6\ ksi) - (2)(2.375\ in) =$ **15.96 in > 8 in - OK**

Therefore use #6 at 8 in OC

Temperature and Shrinkage (AASHTO 5.10.8)

$A_{sT\&S} = 1.30(b)(h)/(2)(b + h)f_y = 1.30(12\ in)(12\ in)/(2(12\ in + 12\ in)(60ksi)) = .065\ in^2$
$0.11 > A_{sT\&S} > 0.065 - 0.11\ in^2$ controls

Provide minimum of #4 bar at 18 in OC, $A_s = 0.133\ in^2/ft$

Top Slab: $M_u = 8.77$ k-ft/ft

Minimum Flexural (AASHTO 5.7.3.3.2)

$1.33\ M_u$
$1.33(M_u) = 1.33(8.77\ k\text{-}ft/ft) =$ **11.7 k-ft/ft – Controls**

-or-

$1.2M_{cr}$
$I_g = bd^3/12 = (12\ in)(10\ in)^3/12 = 1000\ in^4$
$S_g = bd^2/6 = (12\ in)(10\ in)^2/6 = 200\ in^3$
$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6}\ ksi) = .906\ ksi$
$1.2M_{cr} = 1.2(S_g)(f_r) = 1.2(200\ in^3)(.906\ ksi) = 217.4\ k\text{-}in = 18.1\ k\text{-}ft > 11.7\ k\text{-}ft/ft$

Try #6 at 12 in spacing

$A_s = .44\ in^2$
$T = C = A_s*f_y = (.44\ in^2)(60\ ksi) = 26.4\ k$
$a = A_s*f_y/(.85*f'_c*b) = (26.4\ k)/(.85*6\ ksi*12\ in) = 0.43\ in$

$d = 10 \text{ in} - 2 \text{ in} - .625 \text{ in}/2 = 7.6875 \text{ in}$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s * f_y (d-a/2) = (0.90)(0.44 \text{ in}^2)(60 \text{ ksi})(7.6875 \text{ in} - (.43 \text{ in}/2)) = 178 \text{ k-in} = 14.8 \text{ k-ft/ft} >$
11.7 k-ft/ft – OK

Crack Control (AASHTO 5.7.3.4)

$\gamma_e = 0.75$ (Class 2)
$A_s = .44 \text{ in}^2$
$f_{ss} = [M_u/(d-(a/2))]/A_s = [5.10 \text{ k-ft/ft}(12 \text{ in/ft}) /(7.6875 \text{ in} - (.43 \text{ in}/2))]/0.44 \text{ in}^2 = 18.6 \text{ ksi}$
$d_c = 2 \text{ in} + .625/2 = 2.3125 \text{ in}$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.3125 \text{ in}/(0.7(10 \text{ in} - 2.3125 \text{ in})) = 1.43$
$S \leq (700*\gamma_e)/(\beta* f_{ss}) - 2d_c = (700*0.75)/(1.43*18.6 \text{ ksi}) - (2)(2.3125 \text{ in}) =$ **15.1 in > 10 in – OK**

Therefore use #6 at 12 in OC

Cutoff reinforcing in slab

At approximately 1'8", $M_u = 0$ k-ft/ft. Per ACI 12.10, extend h or $l_n/16$ – use 1 ft. Extend bar minimum of 2'8".

Bottom Slab: $M_u = -10.12$ k-ft/ft

Minimum Flexural (AASHTO 5.7.3.3.2)

$1.33 M_u$
$1.33(M_u) = 1.33(10.12 \text{ k-ft/ft}) =$ **13.5 k-ft/ft – Controls**

-or-

$1.2M_{cr}$
$I_g = bd^3/12 = (12 \text{ in})(10 \text{ in})^3/12 = 1000 \text{ in}^4$
$S_g = bd^2/6 = (12 \text{ in})(10 \text{ in})^2/6 = 200 \text{ in}^3$
$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6} \text{ ksi}) = .906 \text{ ksi}$
$1.2M_{cr} = 1.2(S_g)(f_r) = 1.2(200 \text{ in}^3)(.906 \text{ ksi}) = 217 \text{ k-in} = 18.1 \text{ k-ft} > 13.5 \text{ k-ft/ft}$

Try #6 at 12 in spacing

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$A_s = .44\ in^2$
$T = C = A_s*f_y = (.44\ in^2)(60\ ksi) = 26.4\ k$
$a = A_s*f_y/(.85*f'_c*b) = (26.4\ k)/(.85*6\ ksi*12\ in) = 0.43\ in$
$d = 10\ in – 2\ in - .625\ in/2 = 7.6875\ in$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s*\ f_y\ (d-a/2) = (0.90)(0.44\ in^2)(60\ ksi)(7.6875\ in - (.43\ in/2)) = 178\ k\text{-}in = 14.8\ k\text{-}ft/ft >$
$13.5\ k\text{-}ft/ft$ – OK

Crack Control (AASHTO 5.7.3.4)

$\gamma_e = 0.75$ (Class 2)
$A_s = .44\ in^2$
$f_{ss} = [M_u/(d-(a/2))]/A_s = [6.15\ k\text{-}ft/ft(12\ in/ft)\ /(7.6875\ in – (.43\ in/2))]/0.44\ in^2 = 22.4\ ksi$
$d_c = 2\ in + .625/2 = 2.3125\ in$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.3125\ in/(0.7(10\ in – 2.3125\ in)) = 1.43$
$S \leq (700*\gamma_e)/(\beta*\ f_{ss}) - 2d_c = (700*0.75)/(1.43*22.4\ ksi) – (2)(2.3125\ in) = 11.8\ in < 12\ in$ – NG

Try #6 at 10 in spacing

$\gamma_e = 0.75$ (Class 2)
$A_s = .528\ in^2$
$a = A_s*f_y/(.85*f'_c*b) = (31.7\ k)/(.85*6\ ksi*12\ in) = 0.52\ in$
$f_{ss} = [M_u/(d-(a/2))]/A_s = [6.15\ k\text{-}ft/ft(12\ in/ft)\ /(7.6875\ in – (.52\ in/2))]/0.528\ in^2 = 18.8\ ksi$
$d_c = 2\ in + .625/2 = 2.3125\ in$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.3125\ in/(0.7(10\ in – 2.3125\ in)) = 1.43$
$S \leq (700*\gamma_e)/(\beta*\ f_{ss}) - 2d_c = (700*0.75)/(1.43*18.8\ ksi) – (2)(2.3125\ in) =$ **14.9 in > 10 in – OK**

Therefore use #6 at 10 in OC

Temperature and Shrinkage (AASHTO 5.10.8)

$A_{sT\&S} = 1.30(b)(h)/(2)(b + h)f_y = 1.30(12\ in)(12\ in)/(2(12\ in + 12\ in)(60ksi)) = .065\ in^2$
$0.11 > A_{sT\&S} > 0.065$ – $0.11\ in^2$ controls

Provide minimum of #4 bar at 18 in OC, $A_s = 0.133\ in^2/ft$

Bottom Slab: $M_u = 6.86\ k\text{-}ft/ft$

Minimum Flexural (AASHTO 5.7.3.3.2)

$1.33\ M_u$
$1.33(M_u) = 1.33(6.86\text{ k-ft/ft}) =$ **9.1 k-ft/ft – Controls**

-or-

$1.2M_{cr}$
$I_g = bd^3/12 = (12\text{ in})(10\text{ in})^3/12 = 1000\text{ in}^4$
$S_g = bd^2/6 = (12\text{ in})(10\text{ in})^2/6 = 200\text{ in}^3$
$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6}\text{ ksi}) = .906\text{ ksi}$
$1.2M_{cr} = 1.2(S_g)(f_r) = 1.2(200\text{ in}^3)(.906\text{ ksi}) = 217.4\text{ k-in} = 18.1\text{ k-ft} > 9.1\text{ k-ft/ft}$

Try #6 at 12 in spacing

$A_s = .44\text{ in}^2$
$T = C = A_s*f_y = (.44\text{ in}^2)(60\text{ ksi}) = 26.4\text{ k}$
$a = A_s*f_y/(.85*f'_c*b) = (26.4\text{ k})/(.85*6\text{ ksi}*12\text{ in}) = 0.43\text{ in}$
$d = 10\text{ in} – 2\text{ in} - .625\text{ in}/2 = 7.6875\text{ in}$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s*\ f_y\ (d-a/2) = (0.90)(0.44\text{ in}^2)(60\text{ ksi})(7.6875\text{ in} - (.43\text{ in}/2)) = 178\text{ k-in} = 14.8\text{ k-ft/ft} >$
9.1 k-ft/ft – OK

Crack Control (AASHTO 5.7.3.4)

$\gamma_e = 0.75$ (Class 2)
$A_s = .44\text{ in}^2$
$f_{ss} = [M_u/(d-(a/2))]/A_s = [4.59\text{ k-ft/ft}(12\text{ in/ft})/(7.6875\text{ in} – (.43\text{ in}/2))]/0.44\text{ in}^2 = 16.8\text{ ksi}$
$d_c = 2\text{ in} + .625/2 = 2.3125\text{ in}$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.3125\text{ in}/(0.7(10\text{ in} – 2.3125\text{ in})) = 1.43$
$S \leq (700*\gamma_e)/(\beta*\ f_{ss}) - 2d_c = (700*0.75)/(1.43*16.8\text{ ksi}) – (2)(2.3125\text{ in}) =$ **17.2 in > 12 in – OK**

Therefore use #6 at 12 in OC

Wall Slab: M_u = 8.79 k-ft/ft

Minimum Flexural (AASHTO 5.7.3.3.2)

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$1.33\ M_u$
$1.33(M_u) = 1.33(8.79\text{ k-ft/ft}) =$ **11.7 k-ft/ft – Controls**

-or-

$1.2M_{cr}$
$I_g = bd^3/12 = (12\text{ in})(10\text{ in})^3/12 = 1000\text{ in}^4$
$S_g = bd^2/6 = (12\text{ in})(10\text{ in})^2/6 = 200\text{ in}^3$
$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6}\text{ ksi}) = .906\text{ ksi}$
$1.2M_{cr} = 1.2(S_g)(f_r) = 1.2(200\text{ in}^3)(.906\text{ ksi}) = 217\text{ k-in} = 18.1\text{ k-ft} > 11.7\text{ k-ft/ft}$

Try #6 at 12 in spacing

$A_s = .44\text{ in}^2$
$T = C = A_s{*}f_y = (.44\text{ in}^2)(60\text{ ksi}) = 26.4\text{ k}$
$a = A_s{*}f_y/(.85{*}f'_c{*}b) = (26.4\text{ k})/(.85{*}6\text{ ksi}{*}12\text{ in}) = 0.43\text{ in}$
$d = 10\text{ in} – 2\text{ in} - .625\text{ in}/2 = 7.6875\text{ in}$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s{*}\ f_y\ (d\text{-}a/2) = (0.90)(0.44\text{ in}^2)(60\text{ ksi})(7.6875\text{ in} - (.43\text{ in}/2)) = 178\text{ k-in} =$ **14.8 k-ft/ft > 11.7 k-ft/ft – OK**

<u>Crack Control (AASHTO 5.7.3.4)</u>

$\gamma_e = 0.75$ (Class 2)
$A_s = .44\text{ in}^2$
$f_{ss} = [M_u/(d\text{-}(a/2))]/A_s = [5.11\text{ k-ft/ft}(12\text{ in/ft})/(7.6875\text{ in} – (.43\text{ in}/2))]/0.44\text{ in}^2 = 18.7\text{ ksi}$
$d_c = 2\text{ in} + .625/2 = 2.3125\text{ in}$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.3125\text{ in}/(0.7(10\text{ in} – 2.3125\text{ in})) = 1.43$
$S \leq (700{*}\gamma_e)/(\beta{*}\ f_{ss}) - 2d_c = (700{*}0.75)/(1.43{*}18.7\text{ ksi}) – (2)(2.3125\text{ in}) =$ **15.0 in > 12 in – OK**

Therefore use #6 at 12 in OC

<u>Temperature and Shrinkage (AASHTO 5.10.8)</u>

$A_{sT\&S} = 1.30(b)(h)/(2)(b + h)f_y = 1.30(12\text{ in})(12\text{ in})/(2(12\text{ in} + 12\text{ in})(60\text{ksi})) = .065\text{ in}^2$
$0.11 > A_{sT\&S} > 0.065 – 0.11\text{ in}^2$ controls

Provide minimum of #4 bar at 18 in OC, $A_s = 0.133\text{ in}^2$/ft8

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Shear Design

(AASHTO 5.8.3.3)

Top Slab (monolithic with wall): $\mathbf{V_u = 8.38\ k/ft}$

$V_n = V_c + V_s + V_p$
$V_c = (0.0676\sqrt{f'_c} + 4.6(\frac{As}{bde})(\frac{Vude}{Mu}))bd_e$
$V_c = (0.0676\sqrt{6}\,ksi + 4.6\ (0.44\ in^2/(12\ in * 7.6875\ in)(1))(12\ in)(7.6875\ in) = 17.3\ k$
$V_n = (0.9)(17.3\ k/ft) = \mathbf{15.6\ k/ft > 8.38\ k/ft – OK}$

-or-

$V_n = 0.25f'_c b_v d_v + V_p$
$V_n = 0.25(6\ ksi)(12\ in)(7.6875\ in) = 138\ k/ft$
$V_n = 0.9(138\ k) = 125\ k/ft > 15.6\ k/ft$

Bottom Slab (monolithic with wall): $V_u = 6.80\ k/ft$

$V_n = V_c + V_s + V_p$
$V_c = (0.0676\sqrt{f'_c} + 4.6(\frac{As}{bde})(\frac{Vude}{Mu}))bd_e$
$V_c = (0.0676\sqrt{6}\,ksi + 4.6\ (0.44\ in^2/(12\ in * 7.6875\ in)(1))(12\ in)(7.6875\ in) = 17.3\ k$
$V_n = (0.9)(17.3\ k/ft) = \mathbf{15.6\ k/ft > 6.80\ k/ft – OK}$

-or-

$V_n = 0.25f'_c b_v d_v + V_p$
$V_n = 0.25(6\ ksi)(12\ in)(7.6875\ in) = 138\ k/ft$
$V_n = 0.9(138\ k) = 125\ k/ft > 15.6\ k/ft$

Wall Slab: $V_u = 3.37\ k/ft$

$V_n = V_c + V_s + V_p$
$V_c = (0.0676\sqrt{f'_c} + 4.6(\frac{As}{bde})(\frac{Vude}{Mu}))bd_e$
$V_c = (0.0676\sqrt{6}\,ksi + 4.6\ (0.44\ in^2/(12\ in * 7.6875\ in)(1))(12\ in)(7.6875\ in) = 17.3\ k$
$V_n = (0.9)(17.3\ k/ft) = \mathbf{15.6\ k/ft > 3.37\ k/ft – OK}$

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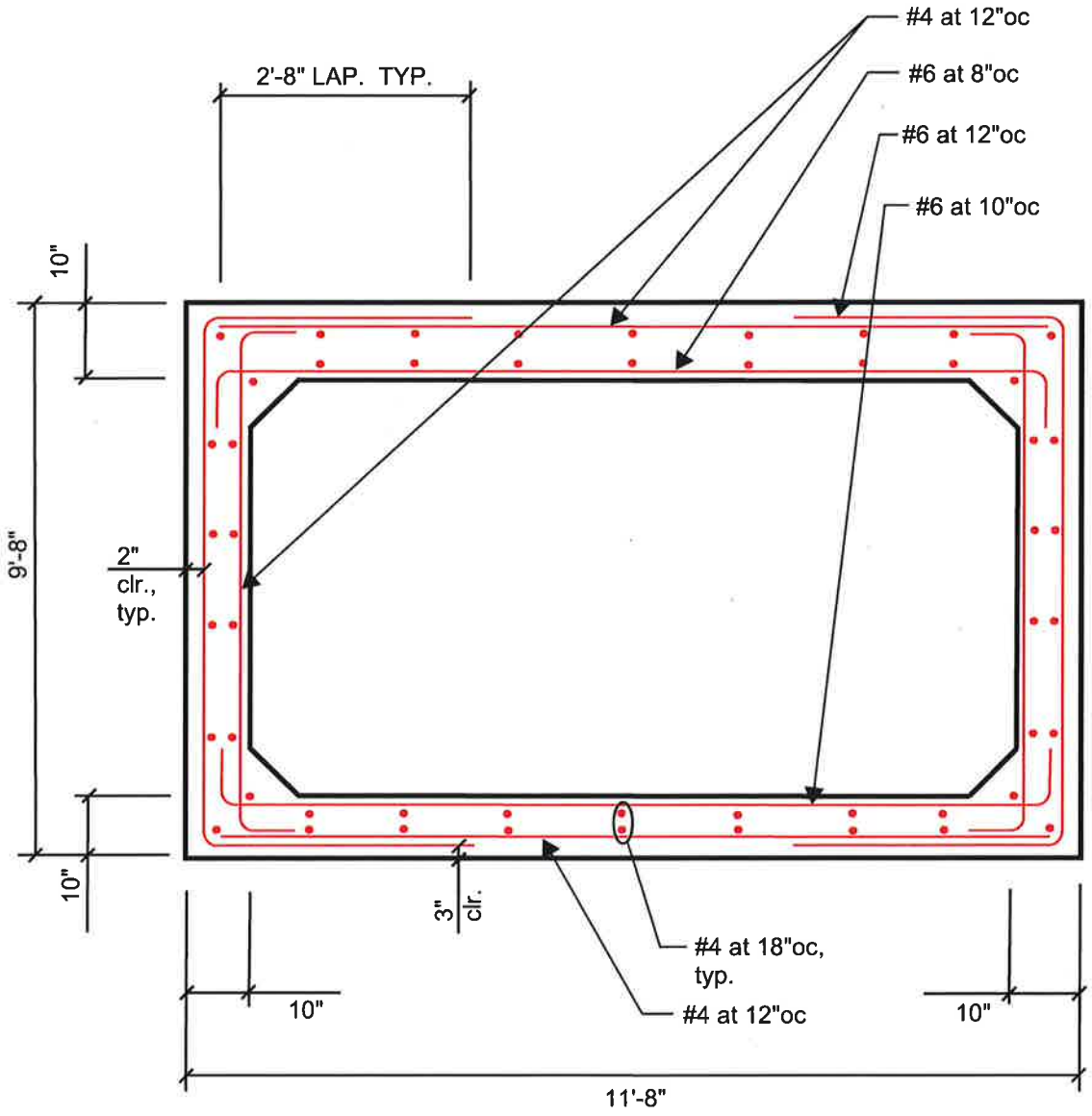
-or-

$V_n = 0.25f'_c b_v d_v + V_p$

$V_n = 0.25(6\ ksi)(12\ in)(7.6875\ in) = 138\ k/ft$

$V_n = 0.9(138\ k) = 125\ k/ft > 3.37\ k/ft$



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Box Culvert End:

Bottom Slab: M_u = -1.94 k-ft/ft

Minimum Flexural (AASHTO 5.7.3.3.2)

1.33 M_u
1.33(M_u) = 1.33(1.94 k-ft/ft) = **2.58 k-ft/ft – Controls**

-or-

1.2M_{cr}
$I_g = bd^3/12 = (12\text{ in})(10\text{ in})^3/12 = 1000\text{ in}^4$
$S_g = bd^2/6 = (12\text{ in})(10\text{ in})^2/6 = 200\text{ in}^3$
$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6}\text{ ksi}) = .906\text{ ksi}$
$1.2M_{cr} = 1.2(S_g)(f_r) = 1.2(200\text{ in}^3)(.906\text{ ksi}) = 217\text{ k-in} = 18.1\text{ k-ft} > 2.58\text{ k-ft/ft}$

Try #4 at 12 in spacing

$A_s = .20\text{ in}^2$
$T = C = A_s*f_y = (.20\text{ in}^2)(60\text{ ksi}) = 12\text{ k}$
$a = A_s*f_y/(.85*f'_c*b) = (12\text{ k})/(.85*6\text{ ksi}*12\text{ in}) = 0.20\text{ in}$
$d = 10\text{ in} – 2\text{ in} - .5\text{ in}/2 = 7.75\text{ in}$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s*f_y(d-a/2) = (0.90)(0.20\text{ in}^2)(60\text{ ksi})(7.75\text{ in} - (.20\text{ in}/2)) = 82.6\text{ k-in} =$ **6.9 k-ft/ft > 2.58 k-ft/ft – OK**

Crack Control (AASHTO 5.7.3.4)

$\gamma_e = 0.75$ (Class 2)
$A_s = .20\text{ in}^2$
$f_{ss} = [M_u/(d-(a/2))]/A_s = [1.39\text{ k-ft/ft}(12\text{ in/ft})/(7.75\text{ in} – (.20\text{ in}/2))]/0.20\text{ in}^2 = 10.9\text{ ksi}$
$d_c = 2\text{ in} + .5/2 = 2.25\text{ in}$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.25\text{ in}/(0.7(10\text{ in} – 2.25\text{ in})) = 1.41$
$S \leq (700*\gamma_e)/(\beta*f_{ss}) - 2d_c = (700*0.75)/(1.41*10.9\text{ ksi}) – (2)(2.25\text{ in}) =$ **29.7 in > 12 in – OK**

Therefore use #4 at 12 in OC

Temperature and Shrinkage (AASHTO 5.10.8)

$A_{sT\&S} = 1.30(b)(h)/(2)(b + h)f_y = 1.30(12\text{ in})(12\text{ in})/(2(12\text{ in} + 12\text{ in})(60\text{ksi})) = .065\text{ in}^2$
$0.11 > A_{sT\&S} > 0.065 - 0.11\text{ in}^2$ controls

Provide minimum of #4 bar at 18 in OC, $A_s = 0.133\text{ in}^2/\text{ft}$

Bottom Slab: $M_u = 3.26$ k-ft/ft

<u>Minimum Flexural (AASHTO 5.7.3.3.2)</u>

$1.33\ M_u$
$1.33(M_u) = 1.33(3.26\text{ k-ft/ft}) =$ **4.34 k-ft/ft – Controls**

-or-

$1.2M_{cr}$
$I_g = bd^3/12 = (12\text{ in})(10\text{ in})^3/12 = 1000\text{ in}^4$
$S_g = bd^2/6 = (12\text{ in})(10\text{ in})^2/6 = 200\text{ in}^3$
$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6}\text{ ksi}) = .906\text{ ksi}$
$1.2M_{cr} = 1.2(S_g)(f_r) = 1.2(200\text{ in}^3)(.906\text{ ksi}) = 217.4\text{ k-in} = 18.1\text{ k-ft} > 4.34\text{ k-ft/ft}$

Try #4 at 12 in spacing

$A_s = .20\text{ in}^2$
$T = C = A_s*f_y = (.20\text{ in}^2)(60\text{ ksi}) = 12\text{ k}$
$a = A_s*f_y/(.85*f'_c*b) = (12\text{ k})/(.85*6\text{ ksi}*12\text{ in}) = 0.20\text{ in}$
$d = 10\text{ in} - 2\text{ in} - .5\text{ in}/2 = 7.75\text{ in}$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s*\ f_y\ (d-a/2) = (0.90)(0.20\text{ in}^2)(60\text{ ksi})(7.75\text{ in} - (.20\text{ in}/2)) = 82.6\text{ k-in} =$ **6.9 k-ft/ft > 4.34 k-ft/ft – OK**

<u>Crack Control (AASHTO 5.7.3.4)</u>

$\gamma_e = 0.75$ (Class 2)
$A_s = .20\text{ in}^2$
$f_{ss} = [M_u/(d-(a/2))]/A_s = [2.44\text{ k-ft/ft}(12\text{ in/ft})/(7.75\text{ in} - (.20\text{ in}/2))]/0.20\text{ in}^2 = 19.4\text{ ksi}$
$d_c = 2\text{ in} + .5/2 = 2.25\text{ in}$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.25\text{ in}/(0.7(10\text{ in} - 2.25\text{ in})) = 1.41$
$S \leq (700*\gamma_e)/(\beta*\ f_{ss}) - 2d_c = (700*0.75)/(1.41*19.4\text{ ksi}) - (2)(2.25\text{ in}) =$ **14.7 in > 12 in – OK**

Therefore use #4 at 12 in OC

Wall Slab: M_u = 3.25 k-ft/ft

Minimum Flexural (AASHTO 5.7.3.3.2)

1.33 M_u
1.33(M_u) = 1.33(3.25 k-ft/ft) = **4.31 k-ft/ft – Controls**

-or-

1.2M_{cr}
$I_g = bd^3/12 = (12\text{ in})(10\text{ in})^3/12 = 1000\text{ in}^4$
$S_g = bd^2/6 = (12\text{ in})(10\text{ in})^2/6 = 200\text{ in}^3$
$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6}\text{ ksi}) = .906\text{ ksi}$
$1.2M_{cr} = 1.2(S_g)(f_r) = 1.2(200\text{ in}^3)(.906\text{ ksi}) = 217\text{ k-in} = 18.1\text{ k-ft} > 4.31\text{ k-ft/ft}$

Try #4 at 12 in spacing

$A_s = .20\text{ in}^2$
$T = C = A_s*f_y = (.20\text{ in}^2)(60\text{ ksi}) = 12\text{ k}$
$a = A_s*f_y/(.85*f'_c*b) = (12\text{ k})/(.85*6\text{ ksi}*12\text{ in}) = 0.20\text{ in}$
$d = 10\text{ in} – 2\text{ in} - .5\text{ in}/2 = 7.75\text{ in}$
$M_r = \varphi M_n$
$\Phi = 0.90$
$M_r = \varphi A_s*f_y(d-a/2) = (0.90)(0.20\text{ in}^2)(60\text{ ksi})(7.75\text{ in} - (.20\text{ in}/2)) = 82.6\text{ k-in} =$ **6.9 k-ft/ft > 4.31 k-ft/ft – OK**

Crack Control (AASHTO 5.7.3.4)

$\gamma_e = 0.75$ (Class 2)
$A_s = .20\text{ in}^2$
$f_{ss} = [M_u/(d-(a/2))]/A_s = [2.42\text{ k-ft/ft}(12\text{ in/ft})/(7.75\text{ in} – (.20\text{ in}/2))]/0.20\text{ in}^2 = 19.0\text{ ksi}$
$d_c = 2\text{ in} + .5/2 = 2.25\text{ in}$
$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 2.25\text{ in}/(0.7(10\text{ in} – 2.25\text{ in})) = 1.41$
$S \leq (700*\gamma_e)/(\beta*f_{ss}) - 2d_c = (700*0.75)/(1.41*19.0\text{ ksi}) – (2)(2.25\text{ in}) =$ **15.1 in > 12 in – OK**

Therefore use #4 at 12 in OC

Temperature and Shrinkage (AASHTO 5.10.8)

$A_{sT\&S} = 1.30(b)(h)/(2)(b + h)f_y = 1.30(12\text{ in})(12\text{ in})/(2(12\text{ in} + 12\text{ in})(60\text{ksi})) = .065\text{ in}^2$
$0.11 > A_{sT\&S} > 0.065 - 0.11\text{ in}^2$ controls

Provide minimum of #4 bar at 18 in OC, $A_s = 0.133\text{ in}^2/\text{ft}$8

Shear Design

(AASHTO 5.8.3.3)

Bottom Slab (monolithic with wall): $V_u = 1.98$ k/ft

$V_n = V_c + V_s + V_p$
$V_c = (0.0676\sqrt{f'_c} + 4.6(\frac{As}{bde})(\frac{Vude}{Mu}))bd_e$
$V_c = (0.0676\sqrt{6}\,ksi + 4.6\,(0.20\text{ in}^2/(12\text{ in} * 7.75\text{ in})(1))(12\text{ in})(7.75\text{ in}) = 16.3\text{ k}$
$V_n = (0.9)(16.3\text{ k/ft}) =$ **14.7 k/ft > 1.98 k/ft – OK**

-or-

$V_n = 0.25f'_c b_v d_v + V_p$
$V_n = 0.25(6\text{ ksi})(12\text{ in})(7.75\text{ in}) = 140\text{ k/ft}$
$V_n = 0.9(140\text{ k}) = 126\text{ k/ft} > 14.7\text{ k/ft}$

Wall Slab: $V_u = 3.25$ k/ft

$V_n = V_c + V_s + V_p$
$V_c = (0.0676\sqrt{f'_c} + 4.6(\frac{As}{bde})(\frac{Vude}{Mu}))bd_e$
$V_c = (0.0676\sqrt{6}\,ksi + 4.6\,(0.20\text{ in}^2/(12\text{ in} * 7.75\text{ in})(1))(12\text{ in})(7.75\text{ in}) = 16.3\text{ k}$
$V_n = (0.9)(16.3\text{ k/ft}) =$ **14.7 k/ft > 3.25 k/ft – OK**

-or-

$V_n = 0.25f'_c b_v d_v + V_p$
$V_n = 0.25(6\text{ ksi})(12\text{ in})(7.75\text{ in}) = 140\text{ k/ft}$
$V_n = 0.9(140\text{ k}) = 126\text{ k/ft} > 14.7\text{ k/ft}$

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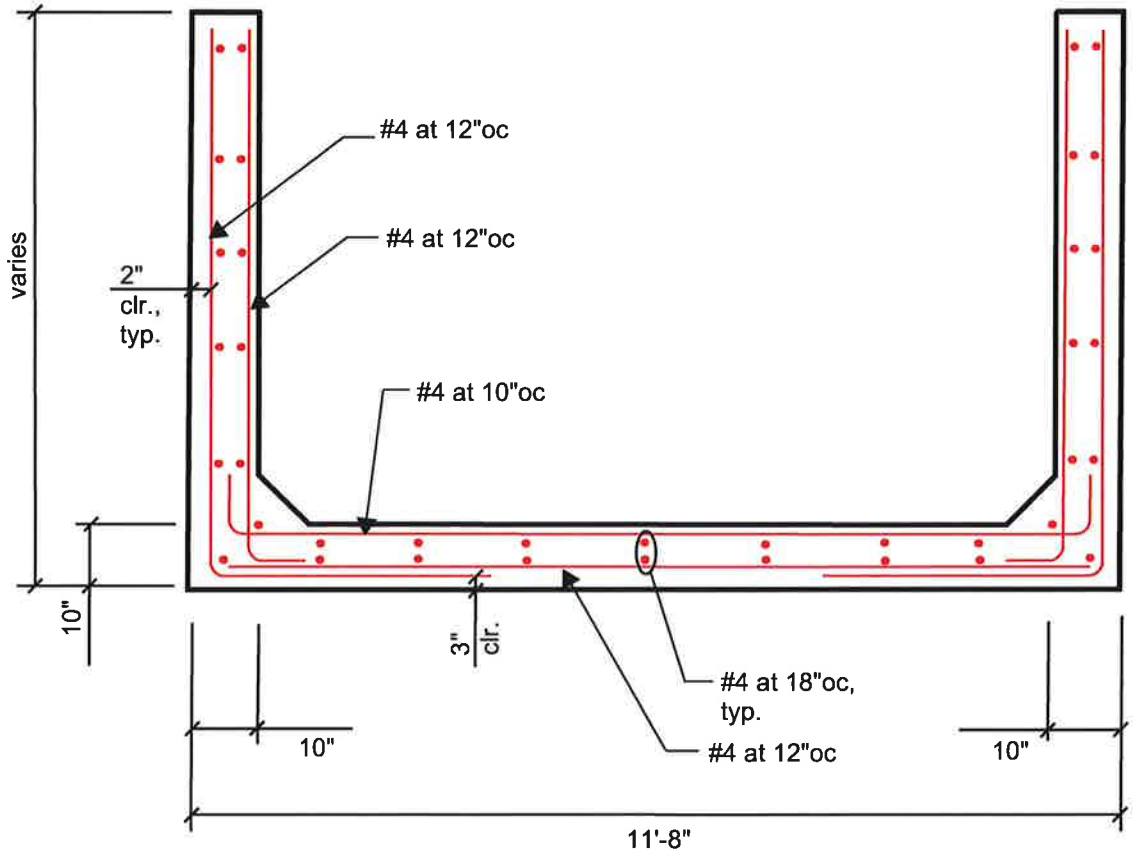

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Headwall

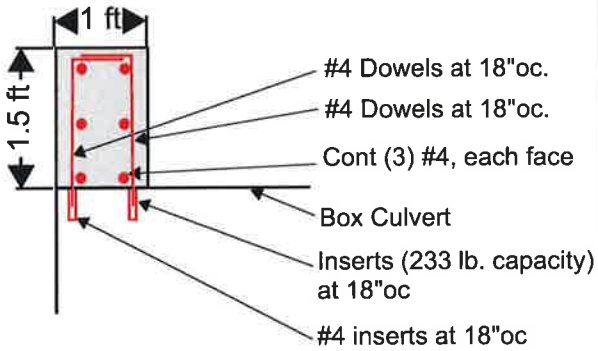
$\beta = 0°$

$k_A = \frac{\cos\beta - \sqrt{[(\cos\beta)^2 - (\cos\varphi)^2]}}{\cos\beta + \sqrt{[(\cos\beta)^2 - (\cos\varphi)^2]}} = \frac{\cos 0 - \sqrt{[(\cos 0)^2 - (\cos 32)^2]}}{\cos 0 + \sqrt{[(\cos 0)^2 - (\cos 32)^2]}} = 0.307$

$k_o = 1 - \sin\varphi = 1 - \sin 32 = 0.47$

$V_u = \gamma_s * H^2 * k_A/2 + \gamma_s * h^2 * k_o/2 = (140\text{ pcf})(1.5\text{ ft})^2(0.307)/2 = .048\text{ k/ft}$

$M_u = 1.35(Wl/3) = 1.35(0.5)(140\text{ lb/ft})(3)/3 = 95\text{ lb-ft/ft}$



Minimum Flexural (AASHTO 5.7.3.3.2)

$1.33\ M_u$

$1.33(M_u) = 1.33(95\text{ lb-ft/ft}) =$ **126 lb-ft/ft – Controls**

-or-

$1.2M_{cr}$

$d = 12\text{ in} - 3\text{in} - .5\text{ in}/2 = 8.75\text{ in.}$

$I_g = bd^3/12 = (12\text{ in})(8.75\text{ in})^3/12 = 670\text{ in}^4$

$S_g = bd^2/6 = (12\text{ in})(8.75\text{ in})^2/6 = 153\text{ in}^3$

$f_r = 0.37\sqrt{f'_c} = 0.37(\sqrt{6}\text{ ksi}) = .906\text{ ksi}$

$M_{cr} = (S_g)(f_r) = (153\text{ in}^3)(.906\text{ ksi}) = 139\text{ k-in} = 11.6\text{ k-ft} > 126\text{ lb-ft}$

Try #4 at 18 in spacing

$A_s = 0.133\text{ in}^2$

$T = C = A_s * f_y = (0.133\text{ in}^2)(60\text{ ksi}) = 8\text{ k}$

$a = A_s * f_y/(.85 * f'_c * b) = (8\text{ k})/(.85 * 6\text{ ksi} * 12\text{ in}) = 0.13\text{ in}$

$M_r = \varphi M_n$

$\Phi = 0.90$

$M_r = \varphi A_s * f_y\ (d-a/2) = (0.90)(0.133\text{ in}^2)(60\text{ ksi})(8.75\text{ in} - (0.13\text{ in}/2)) = 62\text{ k-in} =$ **5.2 k-ft > 126 lb-ft/ft – OK**

Crack Control (AASHTO 5.7.3.4)

$\gamma_e = 0.75$ (Class 2)

$f_{ss} = [M_u/(d-(a/2))]/A_s = [126\text{ lb-ft/ft}(12\text{ in/ft})/(8.75\text{ in} - (.13\text{ in}/2))]/0.133\text{ in}^2 = 1.31\text{ ksi}$

$d_c = 3\text{ in} + .5/2 = 3.25\text{ in}$

$\beta = 1 + d_c/(0.7(h - d_c) = 1 + 3.25\text{ in}/(0.7(10\text{ in} - 3.25\text{ in})) = 1.35$

$S \leq (700 * \gamma_e)/(\beta * f_{ss}) - 2d_c = (700 * 0.75)/(1.35 * 1.31\text{ ksi}) - (2)(3.25\text{ in}) =$ **290 in > 18 in – OK**

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Therefore use #4 at 18 in OC.

d = 12 in – 3 in – 2 in – .5 = 6.5 in
$P = M_u/d$ = 126 lb-ft/ft/((6.5 in)/12in/ft) = 233 lb/ft

Therefore use plastic inserts with a capacity of 233 lb at 18 in OC.

Temperature and Shrinkage (AASHTO 5.10.8)

$A_{sT\&S} = 1.30(b)(h)/(2)(b + h)f_y = 1.30(12\text{ in})(12\text{ in})((2(12\text{ in} + 12\text{ in})(60\text{ksi})) = .065\text{ in}^2$
$0.11 > A_{sT\&S} > 0.065$ – 0.11 in^2 controls

Provide minimum of #4 bar at 18 in OC, $A_s = 0.133\text{ in}^2/\text{ft}$

Cutoff Wall

Temperature and Shrinkage (AASHTO 5.10.8)

$A_{sT\&S} = 1.30(b)(h)/(2)(b + h)f_y = 1.30(12\text{ in})(12\text{ in})((2(12\text{ in} + 12\text{ in})(60\text{ksi})) = .065\text{ in}^2$
$0.11 > A_{sT\&S} > 0.065$ – 0.11 in^2 controls

Provide minimum of #4 bar at 18 in OC, $A_s = 0.133\text{ in}^2/\text{ft}$