APPENDIX 4.4

CONVEYANCE CONCRETE DESIGN CALCULATIONS

CLIENT Sun Oil		JOB NUMBER RC-0086	
SUBJECT Concrete Trench Design			
BASED ON		DRAWING NUMBER	
BY J. Schmohl	CHECKED BY	APPROVED BY	DATE

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CLIENT	JOB NUMBER
SUN OIL	RC-0086

SUBJECT: CONCRETE TRENCH DESIGN

BASED ON	DRAWING NUMBER
ACI 350R-89 ALTERNATE DESIGN METHOD	

BY	CHECKED BY	APPROVED BY	DATE
M DYE	J. Schmohl		10/7/92

THE CONCRETE TRENCH WILL BE DESIGNED USING ACI 350R-89 ALTERNATE DESIGN METHOD (SECT 2.6.7 ACI 350) AS INDICATED BY THE PRELIMINARY CONCRETE TRENCH DESIGN (SEE APPENDIX, p. N_1-N_{18}).

Actually Appendix "A" JGS

SECTION 2.6.7 STATES THAT THE ALTERNATE DESIGN METHOD IS WORKING STRESS DESIGN (ACI 318, APPENDIX B). THEREFORE, ACI 318 APPENDIX B WILL BE USED. FIGURES 2.6.7(a) - 2.6.7(c) FROM ACI 350 WILL BE USED TO MEET THE SERVICEABILITY REQUIREMENTS OF THE CODE. (SEE SECT. 2.6.6 OF ACI 350-89.)

SPLICES MUST CONFORM TO ACI 318 (SECT. 2.7 ACI 350)

FIVE DIFFERENT WALL HEIGHTS WILL BE USED FOR ANALYSIS IN AN ATTEMPT TO OPTIMIZE CONSTRUCTION COSTS. (See p. 35, 49, 61, 81, 101 & 119).

DESIGN ASSUMPTIONS

THE MAJORITY OF THE SOIL BORINGS (BORINGS B-37-1 THRU B-37-19) ALONG THE CONVEYANCE TRENCH INDICATE THAT THE UPPER STRATUM OF SOIL IS TYPE "F LOOSE FILL", GENERALLY UNDERLAIN BY TYPE "F DENSE FILL". STRATA "F LOOSE FILL" SOIL WILL BE USED FOR DESIGN CALCULATIONS USING THE AT REST EARTH PRESSURE COEFFICIENT FOR THE SOIL AND THE ACTIVE EARTH PRESSURE COEFFICIENT FOR THE SURCHARGE LOADING. (SEE TABLE 6.0 IN THE PROJECT SOILS REPORT FOR THE SOIL PROPERTIES - APPENDIX P. "A"). (SEE P. "C" IN APPENDIX FOR JUSTIFICATION OF USING "LOOSE" FILL).

400 psf SURCHARGE LOAD FOR FUTURE MAINTENANCE EQUIPMENT
4,000 psi CONCRETE
60,000 psi REBAR

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Minimum Flexural Reinforcing for Trench Walls & Bottoms:

Walls: Per ACI 318-14.1.2, cantilever walls are to be designed in accordance with the flexural design provisions of chapter 10, with minimum horizontal reinforcement per 14.3.3 (ACI 350, Fig. 2.5 gives 0.0028 ratio)

ACI 318-10.5 gives minimum reinforcement requirements for flexural members. CRSI's interpretation (Engineering Data Report No. 22) of ACI 318-10.5 recommends the most conservative interpretation as prudent. This results in using the minimums of 10.5.1, 10.5.2 & 10.5.3, as applicable, for negative moment reinforcement as well as positive moment reinforcement.

The minimum reinforcement per face of a trench wall shall not be less than 0.0018 Ag/2 or #5 @ 12", whichever is larger. Distribution of reinforcement per ACI 318-14.3.4 applies to minimum reinforcement only, so larger amounts of reinforcing as needed for flexure may be outside of the distribution limits of 14.3.4.

Bottom Slab: Since the bottom slab is subjected to axial compression and flexure, analysis must be handled differently than for the cantilever walls of the trench where axial load was neglected. Design for compression members by the provisions of ACI 318-10.9.1 would require a minimum longitudinal reinforcement of 0.01 times the gross concrete area (Ag). Reducing the effectin gross area to one-half the total concrete area for desig in accordance with ACI 318-10.8.4 would still require $A_{s\,min} = 0.005 A_g$, which for a 39" thick slab would result in 2.34 in² per foot of slab width. Since tensio due to flexure controls the design, it does not make sense to make the bottom slab significantly stronger

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Minimum Flexural Reinforcing - Bottom Slab (Cont'd)

for flexure than the walls.

With the bottom slab analysis (for combined flexure and axial load) indicating that tension in the flexural steel controls, it is considered appropriate to design the bottom slab as a wall with compression in accordance with ACI 318-14.4. Due to the significant flexural stress, minimum reinforcement for flexure should be provided in accordance with the procedure given above for walls.

For the design condition of water inside the trench without backfill, the area of steel required for pure tension may (conservatively) be added directly to the steel area required for flexure (service load moment) and the sum compared to minimum flexural steel to arrive at a (trial) reinforcing quantity (top bars).

Finally, an analysis of the concrete slab with top (compression) and bottom (tension) reinforcing will be made using the Strength Design Method for compression members with flexure as discussed in ACI 318-RA.6. This analysis should verify the ability of the reinforced slab to carry the load factored axial load and moment specified in ACI 350-2.6.5.

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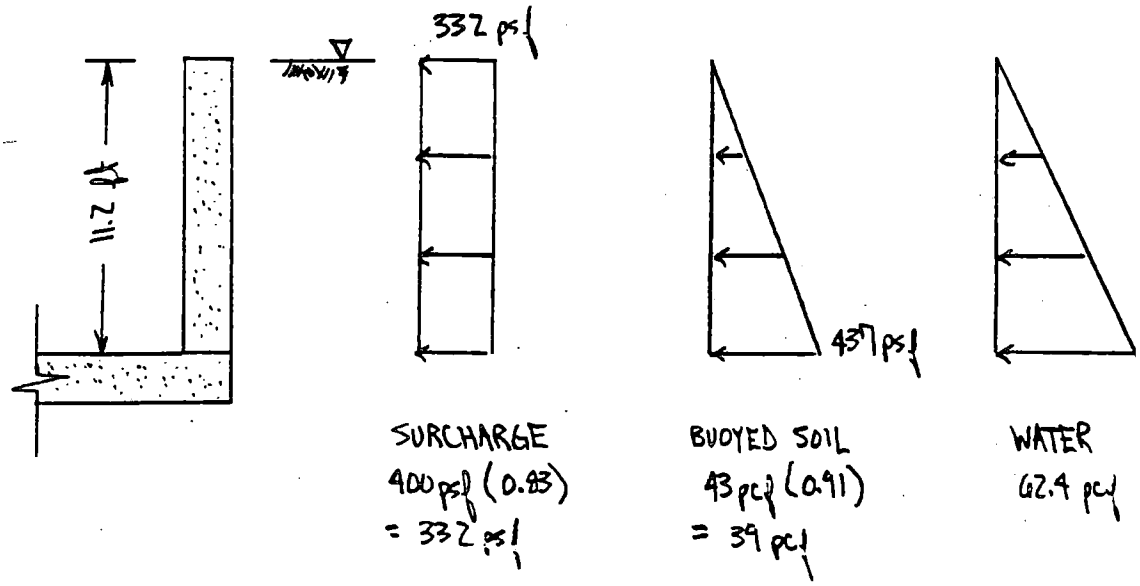
Preliminary Design -
11.2 ft WALL (See Note Below)

WALL LOADS (EXTERIOR FACE)



- RESULTANTS @ BASE OF WALL

SURCHARGE - 332 psf (11.2 ft)(1 ft) = 3,718 lb @ 5.60 ft ABOVE BA
BUOYED SOIL - 1/2 (437 psf)(11.2 ft)(1 ft) = 2,447 lb @ 3.73 ft "
WATER - 1/2 (699 psf)(11.2 ft)(1 ft) = 3,914 lb @ 3.73 ft "

- CHECK SHEAR @ BASE OF WALL

TRY 1'-9" WALL, SAY $d = 21'' - 3''$ (cover) $- \frac{1}{2}''$ ($\frac{1}{2}$ d_b #8) = 17.5"

$V = 3.72^k + 2.45^k + 3.91^k = 10.08^k$

NOTE: Eventually changed to 15.5" (See p. 10)
JSS

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$$v = \frac{V}{b_w d} \quad (\text{ACI } A.7.1)$$

$$v = \frac{10.08^k}{12''(17.5'')} = 0.0480 \text{ ksi} = 48.0 \text{ psi}$$

(Ref. p. 10 w/ $d = 15.5$ $\Rightarrow v = 54$ psi OK)

SHEAR STRESS CARRIED BY CONCRETE (v_c)

ALLOWABLE $v_c = 1.1\sqrt{f'_c}$ (ACI A.7.4.1 & A.3.1 (b))

$$v_c = 1.1\sqrt{4{,}000} = 69.6 \text{ psi}$$

PER ACI A.7.5.5.1 (c), SHEAR REINFORCEMENT NOT REQ'D SINCE "BEAM" DEPTH NOT GREATER THAN ½ THE WIDTH OF THE WEB (½ LENGTH OF WALL)

- FLEXURE @ BASE OF WALL

$$M = 3.72^k(5.60\,ft) + 2.45^k(3.73\,ft) + 3.91^k(3.73\,ft) = 44.6\ ft\cdot k$$

THE FOLLOWING EQUATIONS TO CALCULATE THE REQ'D "d" FOR FLEXURE COME FROM "REINFORCED CONCRETE DESIGN, 4th ed, WANG & SALMON, P. 98.

$$k = \frac{\text{allowable } f_c}{\text{allowable } f_s/n + \text{allowable } f_c}$$

allowable $f_c = 0.45 f'_c$ (ACI

allowable $f_s = 24{,}000$ psi (ACI

$$j = 1 - k/3$$

$n = 8$ (P.91, ABOVE REF.)

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$$M = \tfrac{1}{2}(\text{allowable } f_c)(bkd)(jd)$$

$$M = \tfrac{1}{2} f_c\, bkj\, d^2$$

$$d^2 = \frac{2M}{f_c bkj}$$

$$\text{REQ'D "d"} = \sqrt{\frac{2M}{f_c bkj}}$$

$$\text{allowable } f_c = 0.45(4{,}000\text{ psi}) = 1.80\text{ ksi}$$

$$k = \frac{1.80}{(24\text{ ksi}/8) + 1.80} = 0.3750 = 3/8$$

$$j = 1 - k/3 = 7/8$$

$$\text{REQ'D "d"} = \sqrt{\frac{2(44.6\ \cancel{ft}\cdot k)(12\text{ in}/\cancel{ft})}{1.80\text{ ksi}\,(12\text{ in})(3/8)(7/8)}} = 12.3'' < 17.5\pm'' \text{ PROVIDED}$$

$$A_s = \frac{M}{f_s jd} \qquad \text{(P. 99, WANG \& SALMON, EQ 4.8.5)}$$

$$A_s = \frac{44.6\ \cancel{ft}\cdot k\ (12''/\cancel{ft})}{24\text{ ksi}\,(7/8)(17.5'')} = 1.46\text{ in}^2$$

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- SHEAR FRICTION (ACI A.7.6)

ACI 318 SECT 11.7.5 $V_n \leq 0.2 f'_c A_c = 800 A_c$

ACI 318 SECT A.7.6 $V_n \leq 0.55 (800 A_c)$

$V_n \leq 0.55 (800)(17.5")(12")$

$V_n \leq 92.4^k$ (OK)

ACI 318 SECT. 11.7.2 ⇒ SECT. 11.1.1 & SECT. 11.7.4 & R11.7.4.1

SECT. 11.1.1 $\phi V_n \geq V_u$ (EQ 11-1)

SECT 11.7.4 & R 11.7.4.1

$$A_{vf} = \frac{V_u}{\phi f_y \mu}$$

$\phi = 1.0$ A.2.1

$\mu = 1.0$ 11.7.4.3 ⇒ 11.7.9

(NOTE ON DWG TO INTENTIONALLY ROUGHEN INTERFACE 1/4")

$$A_{vf} = \frac{10.08^k}{1.0(24 ksi)(1.0)}$$

$V_u = V = 10.08^k$ (P. 4)

$f_y = 24$ ksi (ACI A.3.2 (b))

$A_{vf} = 0.42 in^2$

SHEAR FRICTION REQUIRES LESS REINF. STEEL THAN REQUIRED FOR FLEXURE. THEREFORE, FLEXURE CONTROLS. REFER TO ACI 318, R 11.7.7.

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- CRACK CONTROL (ACI 350 SECT 2.6.6)

TRY USING #7 @ 6" $A_s = 1.20\ in^2$

FROM FIG 2.6.7(b) AND Z = 115 $f_{s_{allow}} = 27.3$ ksi

ACI 350 SECT. 2.6.7 ALLOWS THE STRESS IN THE STEEL TO BE INCREASED BASED ON THE Z FACTOR AND BAR SPACING. THEREFORE, $f_{s_{allow}}$ for #7 BAR @ 6" = 27.3 ksi AND NOT 29 ksi AS STATED IN ACI 318 A.3.2 (b).

BASED ON THIS INCREASED ALLOWABLE STRESS, CALCULATE THE STRESS IN THE TENSION STEEL REQUIRED FOR FLEXURE.

$$f_s = \frac{M}{A_s j d}$$ (REARRANGED EQ 4.8.5, P. 99, WANG & SALMON)

$$f_s = \frac{44.6\ ft\cdot k\ (12\ in/ft)}{1.20\ in^2\ (7/8)(17.5")} = 29.1\ ksi$$

$f_s > f_{s_{allow}}$ 29.1 ksi > 27.3 ksi (N.G.)

TRY USING #7 @ 5" $A_s = 1.44\ in^2$ OR #8 @ 6" $A_s = 1.57\ in^2$

#7 @ 5" FROM FIG 2.6.7(b) $f_{s_{allow}} = 29$ ksi

$$f_s = \frac{44.6\ ft\cdot k\ (12\ in/ft)}{1.44\ in^2\ (7/8)(17.5")} = 24.3\ ksi$$

Wang & Salmon, Table 3.8.3

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$f_s < f_{s_{allow}}$ 24.3 ksi < 29 ksi (OK)

#8 @ 6"

FROM FIG. 2.6.7 (b) $f_{s_{allow}} = 27.3$ ksi

$$f_s = \frac{44.6\,(12)}{1.57\,(7/8)(17.5")} = 22.3 \text{ ksi}$$

$f_s < f_{s_{allow}}$ 22.3 ksi < 27.3 ksi

CAN USE #7 @ 5" OR #8 @ 6" FOR DOWELS

SUPERSEDED SEE P. 16 #35 FOR FINAL

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BASED ON OUR MEETING THIS MORNING, THE EFFECTIVE DEPTH (d) WILL BE CHANGED TO ALLOW FOR A SHEETPILING TOLERANCE OF ± 3" IN THE LATERAL DIRECTION. THEREFORE,

d = 1'-9" WALL - 3" (SHEETPILE) - 2" (COVER) - 1/2 (BAR DIAMETER)

ASSUMES #8 BAR

d = 21" - 3" - 2" - 1/2(1") = 15.5"

DETERMINE IF #8 @ 6" WILL STILL WORK

SHEAR OK BY INSPECTION FROM PREVIOUS CALCS (See p. 5)

FLEXURAL STEEL:

$$A_s = \frac{M}{f_s j d} = \frac{44.6\ \cancel{ft}\cdot k\,(12\ in/\cancel{ft})}{27.3\ ksi\,(7/8)(15.5\ in)} = 1.45\ in^2$$

$1.45\ in^2 < 1.57\ in^2$ PROVIDED (ok) ; SHEAR FRICTION OK BY INSPECTI FROM PREVIOUS CALCS

#8 @ 6" WILL STILL BE ADEQUATE

SEE P. 20

IN BUOYANCY CALCULATIONS, USE A WALL THICKNESS 3" LESS THAN NOMINAL AND A FACTOR OF SAFETY EQUAL TO 1.0. NOTE THAT FOR THE USUAL BOX-TYPE STRUCTURES, A FACTOR OF SAFETY OF 1.10 IS NORMALLY USED. HOWEVER, IN THE CASE OF THE TRENCH, WE HAVE REDUCED THE WALL THICKNESS A FULL 3" FROM THE NOMINAL DIMENSION, NEGLECTED ANY ANCHORAGE FROM THE SHEETPILES, AND CALCULATED BUOYANCY AT THE DEEPEST SECTION OF THE WALL ASSUMING GROUNDWATER TO THE TOP OF THE WALL. THIS SHOULD PROVIDE ADEQUATE CONSERVATISM.

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GENERAL EQUATION FOR SHEAR (DISTANCE DOWN FROM TOP OF WALL = x)

$$V = \frac{[332\,psf(x)(1\,ft) + \tfrac{1}{2}(39\,pcf)(x)(x)(1\,ft) + \tfrac{1}{2}(62.4\,pcf)(x)(x)(1\,ft)]}{1000}$$

$V = 0.0507x^2 + 0.332x$ "x" IN FEET; "V" IN KIPS

CHECK EQUATION W/ $x = 11.2$ ft

$V = 10.08^k$ (ok) (SEE P. 4 CALCS)

GENERAL EQUATION FOR MOMENT (DISTANCE DOWN FROM TOP OF WALL =

$M = 332\,psf(x)(1\,ft)(x/2) + \tfrac{1}{2}(39\,pcf)(x)(x)(1\,ft)(x/3) + \tfrac{1}{2}(62.4\,pcf)(x)(x)(1$

$M = 166x^2 + 6.5x^3 + 10.4x^3 = 16.9x^3 + 166x^2$

$M = 0.0169x^3 + 0.166x^2$ "x" IN FEET; "M" IN ft·KIPS

Check Equation w/ $x = 11.2'$

$M = 44.6'^k$ (ok) (See p. 5 of Calcs.)

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11.2 ft WALL

4 CASES THAT MUST BE CONSIDERED FOR DETERMINATION OF MINIMUM AREA OF STEEL THAT CAN BE USED (ACI 318-10.5)

1) $M_{ACT} > M_{200/f_y}$ USE M_{ACT}

2) $M_{ACT} < M_{200/f_y} < 4/3\, M_{ACT}$ USE M_{200/f_y}

3) $M_{0.0018/2} < 4/3\, M_{ACT} < M_{200/f_y}$ USE $4/3\, M_{ACT}$

4) $4/3\, M_{ACT} < M_{0.0018/2} < M_{200/f_y}$ USE $M_{0.0018/2}$

$M_{200/f_y} = f_s A_{s_{FLEXURE}}\, j\, d$

$\rho_{FLEXURE} = 200/f_y = 200/60{,}000\ psi = 0.0033$

$A_{s_{FLEXURE}} = \rho_{FLEXURE}(b)(d) = 0.0033(12'')(15.5'') = 0.61\ in^2$

$M_{200/f_y} = 24\ ksi\,(0.61\ in^2)(7/8)(15.5'')(1'/12\ in) = 16.55\ ft\cdot k$

$M_{0.0018/2} = f_s A_{s_{T\&S}}\, j\, d$

$\rho = 0.0018/2$ (EACH FACE)

$A_{s_{T\&S}} = (0.0018/2)(b)(h) = (0.0018/2)(12'')(18'') = 0.19\ in^2$

$M_{0.0018/2} = 24\ ksi\,(0.19\ in^2)(7/8)(15.5'')(1'/12\ in) = 5.15\ ft\cdot k$

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USING THE GENERALIZED MOMENT EQUATION FOR THE EXT. FACE REINFORCEMENT (P. 11) DETERMINE THE DISTANCE DOWN FROM THE TOP OF THE WALL WHERE THESE M_{200/F_y} AND $M_{0.0018/2}$ OCCUR.

$$M_s = 0.0169\,x^3 + 0.166\,x^2$$

DISTANCE DOWN WALL WHERE M_{200/F_y} OCCURS

$$M_{200/F_y} = 16.55\ ft\cdot k$$

$$16.55\ ft\cdot k = 0.0169\,x^3 + 0.166\,x^2 \qquad x = 7.52\ ft$$

DISTANCE DOWN WALL WHERE $M_{0.0018/2}$ OCCURS

$$M_{0.0018/2} = 5.15\ ft\cdot k$$

$$5.15\ ft\cdot k = 0.0169\,x^3 + 0.166\,x^2 \qquad x = 4.60\ ft$$

DISTANCE DOWN WALL WHERE ONE CAN DESIGN THE WALL USING $4/3\ M_{ACI}$.

$$16.55\ ft\cdot k = 4/3\left(0.0169\,x^3 + 0.166\,x^2\right) \qquad x = 6.67\ ft$$

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THE MINIMUM STEEL TO BE USED IN THE WALL IS #5 @ 12" w/ $A_s = 0.31\ in^2$. THIS AREA OF STEEL IS GREATER THAN THAT REQUIRED FOR $M_{0.0018/2}$, THUS TEMP. AND SHRINKAGE REQUIRE HAVE BEEN SATISFIED.

FROM LOOKING AT THE SKETCH ON P. 16, IT SEEMS THAT #5 @ 12" WILL FALL INTO THE REGION WHERE THE WALL STEEL CAN BE DESIGN FOR $4/3\ M_{ACT}$. THEREFORE, FIND THE DISTANCE DOWN THE WALL WHERE #5 @ 12" CAN THEORETICALLY CAN BE USED.

USE $f_s = 21.6$ ksi (CONSERVATIVE FOR ACI 350)
#5 @ 12" : $A_s = 0.31\ in^2$

$$f_s = \frac{M_s}{A_s j d} \quad \therefore$$

$M_{\#5@12} = 21.6\ ksi\,(0.31\ in^2)(7/8)(15.5\ in)/12 =$ ASSUMPTION CORRECT. (4/3

$$21.6\ ksi = \frac{1.33\,(0.0169x^3 + 0.166x^2)(12\ in/1\ ft)}{0.31\ in^2\,(7/8)(15.5\ in)} \qquad x = 4.80\ ft$$

ONCE AGAIN FROM LOOKING AT THE SKETCH ON P. 16, IT SEEMS THAT #8@12" AND #5@12" WILL FALL INTO THE REGION WHERE THE WALL CAN BE DESIGNED FOR THE ACTUAL MOMENT. THEREFORE, FIND THE DISTANCE DOWN THE WALL WHERE #8@12" AND #5@12" CAN THEORETICALLY BE USED.

(WANG & SALMON TABLE 3.8.3)

USE $f_s = 21.6$ ksi (CONSERVATIVE)
#5 @ 12" $A_s = 0.31\ in^2$ #8 @ 12" $A_s = 0.78\ in^2$ $(0.31\ in^2 + 0.78\ in^2) =$

$M_{\#8@12\ \&\ \#5@12} = 21.6\ ksi\,(1.09\ in^2)(7/8)(15.5\ in)/12 = 26.6\ ft\cdot k$ (ASSUMPTION CORREC

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#8 @ 12" & #5 @ 12" (M_{act} CONTROLS)

$$21.6\ ksi = \frac{(0.0169x^3 + 0.166x^2)(12\ in/ft)}{1.09\ in^2\ (7/8)(15.5\ in)} \qquad x = 9.12\ ft$$

Class B SPLICE FOR #5 BAR = 1.3 l_d #5

= 1.3(17.8") = 23.14" USE 2'-0" LAP

l_d #5 (SEE APPENDIX "EMBEDMENT OF DOWELS & STANDARD HOOKS IN SLABS AND WALLS") - P. "K" OF APPENDIX

ACCORDING TO ACI 318 12.10.5 MUST CHECK SHEAR AT THEORETICAL CUTOFF POINT

SHEAR 9.12 ft DOWN FROM TOP OF WALL (P. 11 FOR EQUATION)

$V_s = 0.0507x^2 + 0.332x = 0.0507(9.12\ ft)^2 + 0.332(9.12\ ft) = 7.24^k$

$v = V/bd = 7.24^k / [(12")(15.5")] = 0.0389\ ksi = 38.9\ psi$

$v_{c\ ALLOW} = 69.6\ psi$

$38.9\ psi \leq 2/3\ (69.6\ psi)$

$38.9\ psi < 46.4\ psi$ (OK)

FOR DESIGN SKETCH OF EXT. FACE REINF. SEE P. 16.

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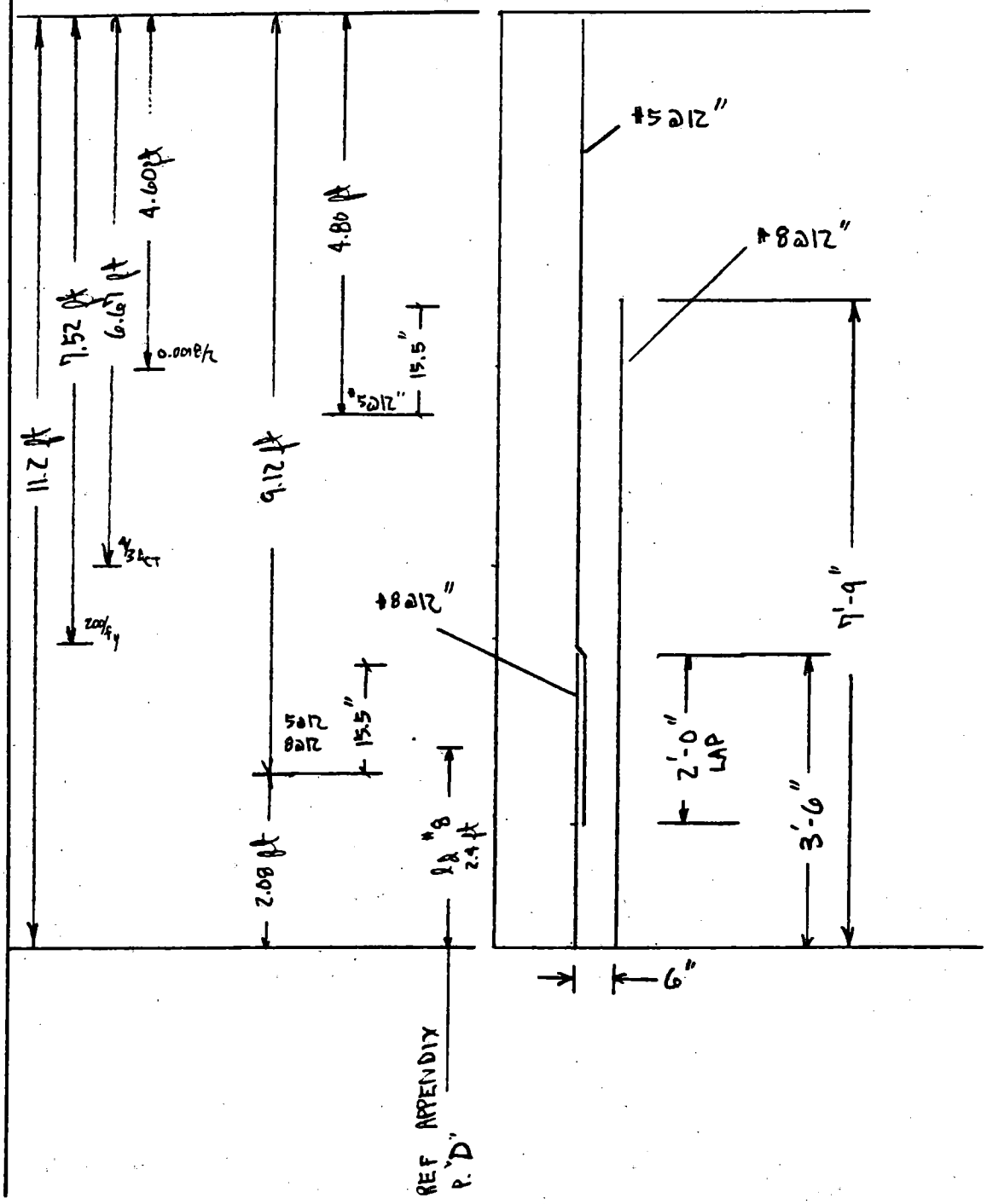
EXT. FACE REINF.



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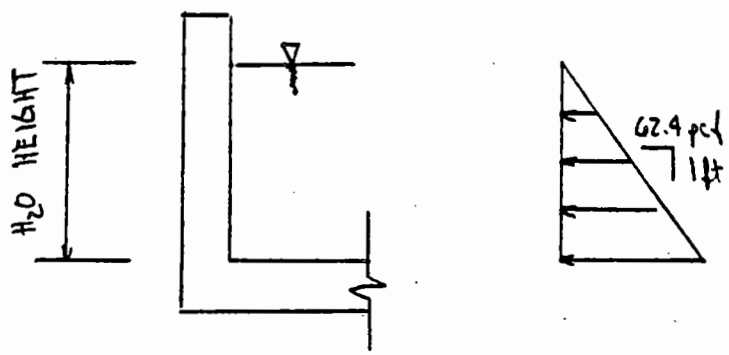
INTERIOR WALL LOAD

THE WATER SURFACE ELEVATIONS @ PEAK FLOW WERE CALCULATED EVERY 200 ft AS TABULATED ON P. J OF APPENDIX. THE MAX. WATER HEIGHT OCCURS AT STATION 35+39.52.



GENERAL EQUATION FOR MOMENT

$$M = \tfrac{1}{2}(62.4\ pcf)(x)(x)(1\ ft)(x/3)/1000$$

"x" IN FEET
"M" IN ft·K

$$M = 0.0104x^3$$

GENERAL EQUATION FOR SHEAR

$$V = \tfrac{1}{2}(62.4\ pcf)(x)(x)(1\ ft)/1000$$

"x" IN FEET
"V" IN KIPS

$$V = 0.0312x^2$$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M. DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/14/92

AT MAX. WATER HEIGHT (7.48 ft)

$M = 0.0104(7.48\ ft)^3 = 4.35\ ft\cdot k < 5.15\ ft\cdot k$ FOR MIN REINF (T & S)

$V = 0.0312\ (7.48\ ft)^2 = 1.75^k$

∴ MIN. REINF .0018/2 #5 @ 12" CONTROLS

DESIGN REINFORCEMENT

DUE TO SUCH A SMALL MOMENT ASSUME #5 @ 12" $A_s = 0.31\ in^2$ CAN BE USED

FROM PAGE E OF APPENDIX $f_s = 22.8$ ksi TO MEET CRACK CONTROL PROVISIONS

$$A_{s\ REQ'D} = \frac{M}{f_s j d} = \frac{4.35\ ft\cdot k\ (12\ in/ft)}{22.8\ ksi\ (7/8)(15.5")}$$

$A_{s\ REQ'D} = 0.17\ in^2$

A_s PROVIDED $> 4/3\ A_{s\ REQ'D}$ (OK)

ACCORDING TO ACI 350 THE MAX. BAR SPACING THAT CAN BE USED IS 12". (ACI 350 FIG 2.6.7(b))

CK SHEAR

SHEAR STESS IN CONCRETE OK BY INSPECTION

CK SHEAR FRICTION

$$A_{vf} = \frac{1.75^k}{(1.0)(24\ ksi)(1.0)} = 0.07\ in^2$$

(FORMULA P. 7 CALCS)
(FLEXURE CONTROLS, ACI 318, R

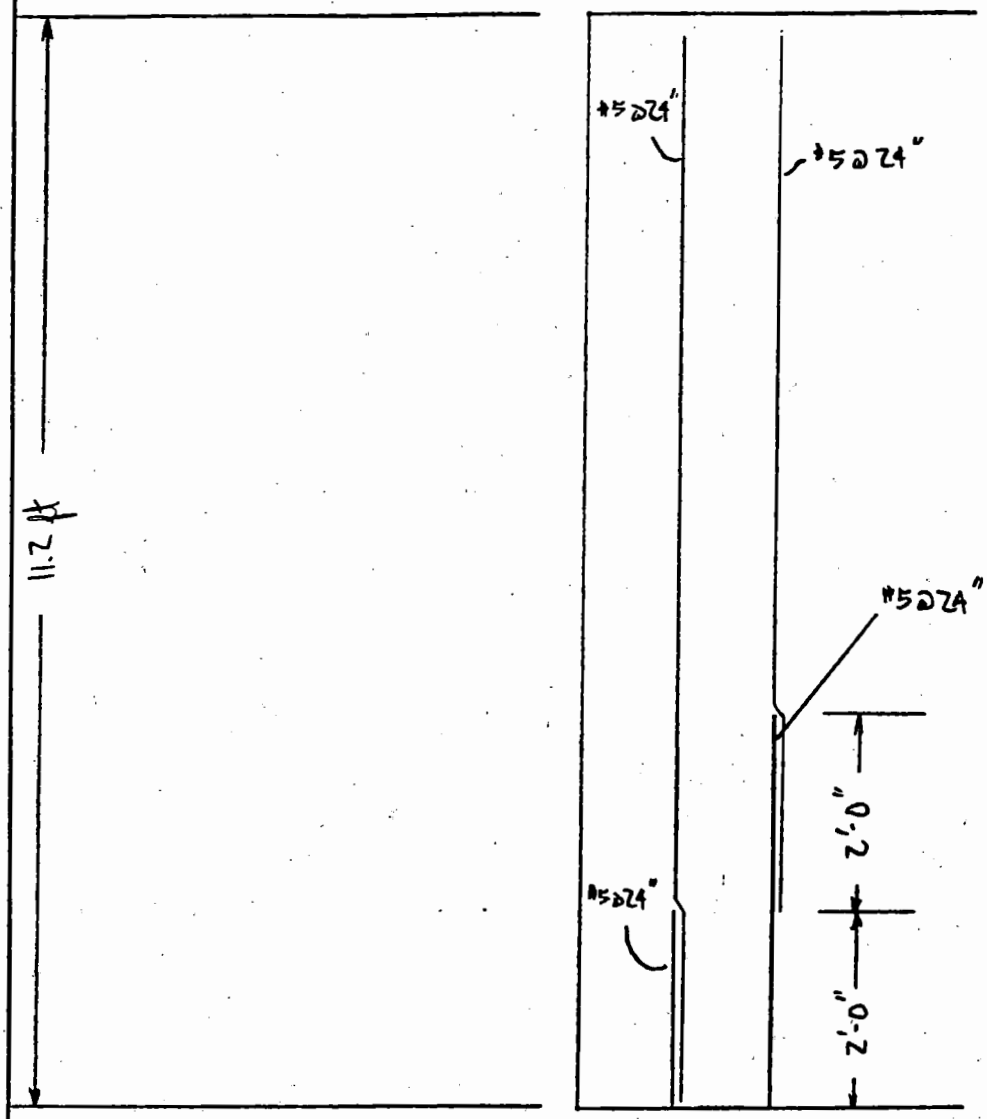
CLIENT	JOB NUMBER
SUN OIL	RC-0086

SUBJECT
CONCRETE TRENCH DESIGN

BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	

BY	CHECKED BY	APPROVED BY	DATE
M. DYE	J. Schmohl		11/2/92

INT. FACE REINF.
(ALL WALLS)



$1.3\, l_d$ #5 = 1.3(17.8") = 23.14" USE 2'-0" LAP

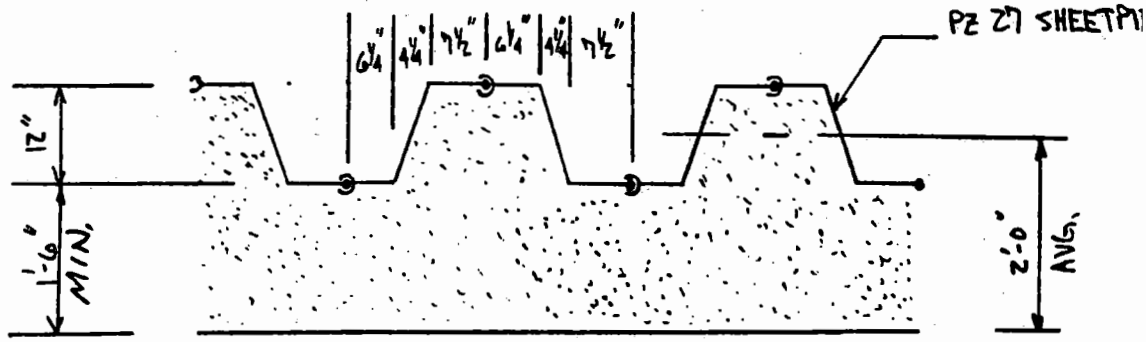
ACI 12.10.5 OK BY INSPECTION

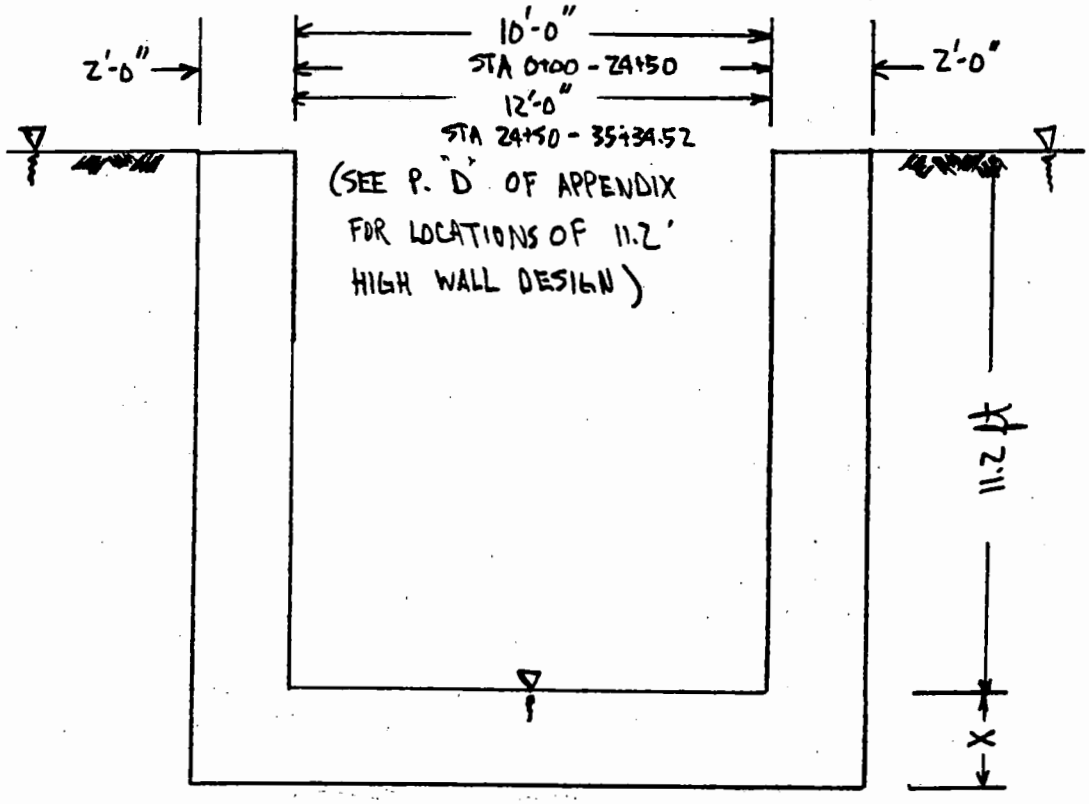
CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmehl	APPROVED BY / DATE: 10/13/92

DESIGN BOTTOM SLAB - 11.2' Deep Trench

THE THICKNESS OF THE BOTTOM SLAB WILL BE GOVERNED BY BUOYANCY.

ASSUME A 1'-6" WALL ALONG WITH THE CONCRETE IN THE CORRUGATIONS OF THE PZ 27 SHEETPILE FOR BUOYANCY CALCULATIONS





CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
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$\uparrow \Sigma F = \downarrow \Sigma F$ (USE A FACTOR OF SAFETY = 1.0)

* STA 0+00 - STA 24+50

$62.4\ pcf\,(14\,ft)(11.2\,ft + x)(1\,ft)/1000 = 2(2\,ft)(11.2\,ft)(1\,ft)(.15\ kcf)$

$+\ 14\,ft(x)(1\,ft)(.15\ kcf)$

$0.87x + 9.78 = 6.72 + 2.1x$

$x = 2.98\ ft$

USE 2'-6" SLAB ; 11.2 ft WALL ; STA 0+00 - STA 2

* STA 24+50 - STA 35+34.52

$62.4\ pcf\,(16\,ft)(11.2\,ft + x)(1\,ft)/1000 = 6.72 + 16\,ft(1\,ft)(x)(.15\ kcf)$

$1.00x + 11.18 = 6.72 + 2.4x$

$x = 3.19\ ft$

USE 3'-3" SLAB ; 11.2 ft WALL ; STA 24+50 - STA

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
AC1 350-89 ALTERNATE DESIGN METHOD	

BY	CHECKED BY	APPROVED BY	DATE
M DYE	J. Schmohl		10/14/92

THE BASE SLAB IS IN COMPRESSION AS WELL AS IN FLEXURE. ACCORDING TO ACI 318 RA.6, THE SLAB MUST BE DESIGNED USING THE STRENGTH DESIGN METHOD. DUE TO USING ACI 350 FOR CRACK CONTROL, ∴ THE ADDITIONAL LOAD FACTORS STATED IN ACI 350 MUST BE USED IN THE STRENGTH DESIGN.

$M_u = [1.7(166x^2) + 1.7(6.5x^3) + 1.7(10.9x^3)]\,(1^K/1000\,lb)$ (P 11 CAL

1.7 FACTOR FOR LIVE LOAD (L) ← (ACI 318 9.2.4)
1.7 FACTOR FOR SOIL LOAD (H) ←
1.7 FACTOR FOR WATER LOAD (F) (ACI 350 2.6.5)

$V_u = [1.7(332)(x) + 1.7(39)(x)(x)(1/2) + 1.7(62.4)(x)(x)(1/2)]/1000^{\#}$

ADDITIONAL SANITARY DURABILITY COEFFICIENT (1.3) (ACI 350 2.

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
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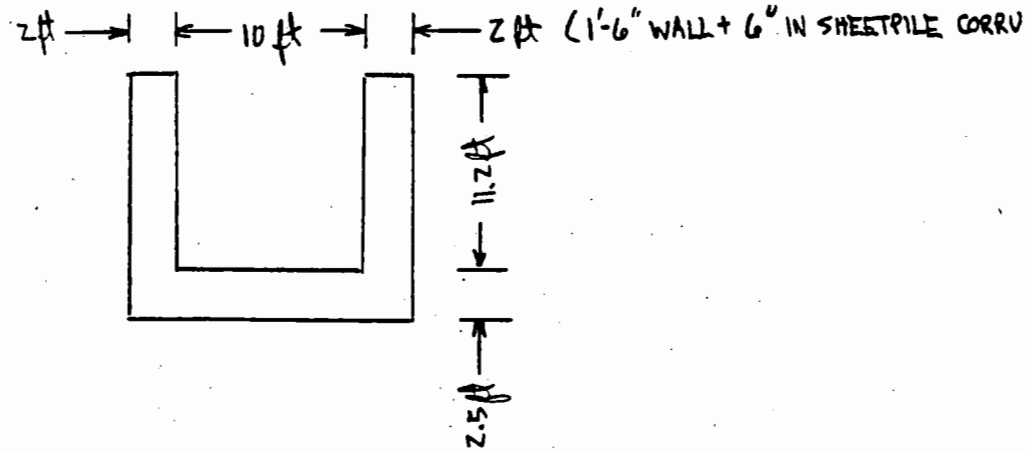
CALCULATE THE MOMENT ON THE BASE SLAB

DUE TO THE TRENCH HAVING DIFFERENT WIDTHS AND SLAB THICKNESSES, TWO ANALYSES ARE REQ'D.

CASE 1

10 ft WIDE TRENCH W/ 2'-6" SLAB

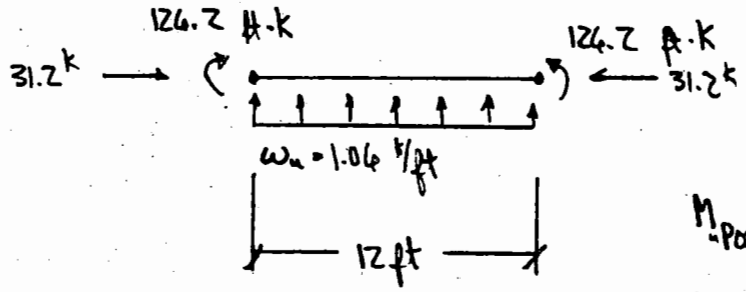


LOAD ACTING ON SLAB = WEIGHT OF WALLS / TRENCH WIDTH

$= 2ft(11.2ft)(1ft)(.15\ kcf)(2\ WALLS) / 14ft$

$= 0.48\ k/ft\ (1.7)(1.3)$ (ACI 350 2.6.5) (ACI 350 2.6.5(a))

$126.2\ ft\cdot k = M_u$
$31.2^k = P_u$
} SEE APPENDIX P. "L"



M_u = STRENGTH DESIGN MO
M_s = SERVICE LOAD MOMEN

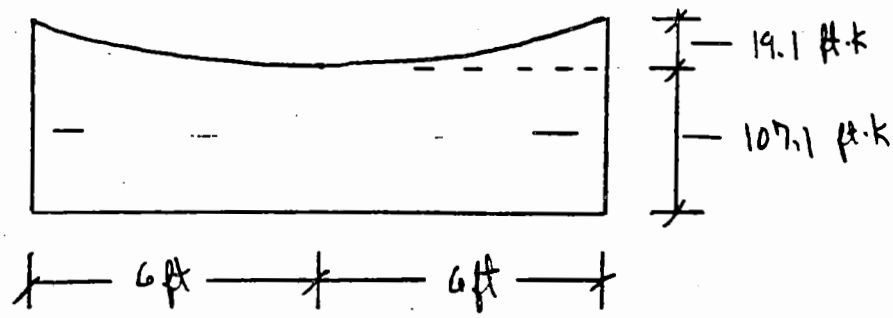
$M_{-POS} = wl^2/8 = 1.06\ k/ft(12ft)^2/8$

$M_{+POS} = 19.1\ ft\cdot k$

$M_{s_{POS}} = 0.48(12ft)^2/8 = 8.64\ ft\cdot k$

CLIENT	JOB NUMBER
SUN OIL	RC-00886
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/19/92

SUPERIMPOSE MOMENTS



CASE 2

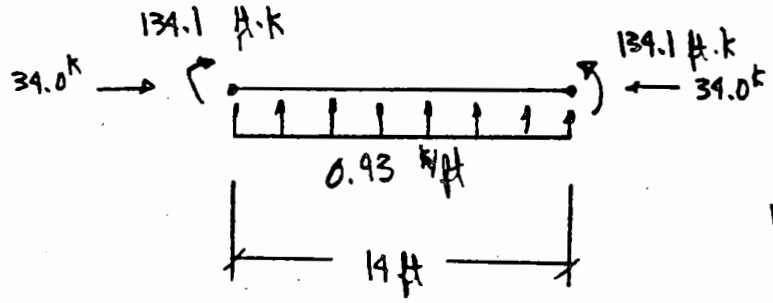
12 ft WIDE TRENCH w/ 3'-3" SLAB

LOAD ACTING ON SLAB = WEIGHT OF WALLS / TRENCH WIDTH

$= 2\,ft(11.2\,ft)(1\,ft)(.15\,kcf)(2\text{ WALLS})/16\,ft$

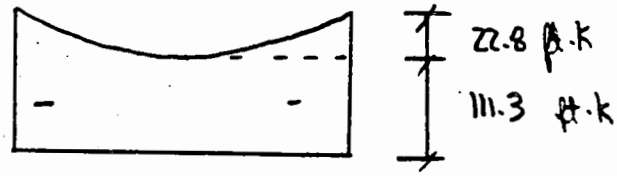
134.1 ft·k = M_u
39.0 k = M_u
} SEE APPENDIX p. "L"

$= 0.42\,k/ft\,(1.7)(1.3)$ (ACI 350 2.6.5)
(ACI 350 2.6.5(a))



$M_{uPOS} = wl^2/8$

$M_{uPOS} = 22.8\,ft\cdot k$



$M_{s_{POS}} = 0.42(14)^2$

$M_{s_{POS}} = 10.29\,ft$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmoll	APPROVED BY / DATE: 10/14/92

DESIGN THE BASE SLABS ON FLEXURE

CASE 1 (SLAB THICKNESS 2'-6"; P21) ASSUME #8 BAR

BOTTOM STEEL

$d = 2.5\,ft - 3''(\text{cover}) - \frac{1}{2}(1'') = 26.5''$

$R_n = M_u/\phi b d^2$ $\phi = 0.90$ (ACI 318 9.3.2.1)

FORMULA (P. 55 WANG & SALMON)

(REF P. 23)

$$R_n = \frac{126.2(12{,}000)}{0.9(12)(26.5)^2} = 200\ psi$$

$$\rho_{REQ'D} = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mR_n}{f_y}}\right)$$ (P. 55 WANG & SALMON (EQ 3.8.5))

$m = f_y/0.85 f'_c$ (P. 55 WANG & SALMON)

$m = 17.65$

$\rho_{REQ'D} = 0.0034$

$\rho_{min} = 200/f_y$ or $1.33\,\rho_{REQ'D}$ or $0.0018\,A_g$ (ACI 10.5.1, 10.5.2, 10.5.3)

$\rho_{min} = 200/f_y = 0.0033$ $\rho_{min} = 1.33(0.0034) = 0.0046$ $\rho_{REQ'D}$ GOVERN

$A_s = \rho b d = 0.0034(12)(26.5) = 1.08\ in^2$

TRY #7 @ 6" $A_s = 1.20\ in^2$

CLIENT	JOB NUMBER
SUN OIL	BC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
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CHECK CRACKING

USING THE ACI 350 ALTERNATE DESIGN METHOD; Z = 115

FROM FIG 26.7(b) ACI 350 $f_{s_{ALLOW}} = 27.3$ ksi. for #7 @ 6"

$$f_{s_{ACTUAL}} = \frac{M_s}{A_s j d}$$

$M_s = 57.1$ ft·k (REF. APPENDIX p. "L")

$$f_{s_{ACTUAL}} = \frac{57.1 \text{ ft·k } (12 \text{ in/ft})}{1.20\,(7/8)(26.5)} = 24.6 \text{ ksi}$$

USE #7 @ 6"

$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ 24.6 ksi < 27.3 ksi (OK)

TOP STEEL

$M_s = 0.0104\,x^3$ TAKE MOMENT @ ℄ SLAB AND SHEAR @ ℄ SLAB

$M_s = 0.0104\,(7.98' + 1.25')^3 = 6.92$ ft·k

$V_s = 0.0312\,(7.98' + 1.25')^2 = 2.38$ k

TRY #6 @ 12" $A_s = 0.44$ in^2

$f_s = 21.6$ ksi (ACI 350 2.6

$$A_{s_{REQ'D\ (FLEXURE)}} = \frac{6.92 \text{ ft·k } (12 \text{ in/ft})}{21.6 \text{ ksi } (7/8)(26.5)} = 0.17 \text{ in}^2$$

$$A_{s_{REQ'D\ (TENSION)}} = \frac{2.38^k}{21.6 \text{ ksi}} = 0.11 \text{ in}^2$$

$$A_{s_{TOTAL}} = \tfrac{4}{3} A_{s_{REQ'D\ (FLEXURE)}} + A_{s_{REQ'D\ (TENSION)}} = 0.34 \text{ in}^2 \longleftarrow \text{GOVERNS}$$

$$A_{s_{MIN}} = 0.0018\,bh/2 = 0.0018\,(12'')(30'')/2 = 0.32 \text{ in}^2$$

USE #6 @ 12

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SUN OIL	RC-0086
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CASE 2

BOTTOM STEEL

SLAB THICKNESS 3'-3" (P. 21) ← ASSUME #8 BAR

$d = 3.25\ ft - 3''(\text{cover}) - \frac{1}{2}(1'') = 35.5''$

(REF. P 24)

$R_n = M_u/\phi b d^2 = 134.1(12{,}000)/[0.90(12)(35.5)^2] = 118\ psi$

$\rho_{REQ'D} = 0.0020$

$\rho_{min} = 200/f_y$ or $1.33\,\rho_{REQ'D}$ or $0.0018 A_g$ (ACI 10.5.1, 10.5.2, 10.5.3)

$\rho_{min} = 0.0033$ $\quad 4/3\,\rho_{REQ'D} = 0.0027$ ← USE THIS

$A_s = \rho b d = 0.0027(12'')(35.5) = 1.15\ in^2$

TRY #7 @ 6" $A_s = 1.20\ in^2$

CHECK CRACKING

ACI 350 FIG 2.6.7(b) $f_{s_{ALLOW}} = 27.3\ ksi$ FOR #7 @ 6"

$d = 34 - 3 - \frac{1}{2}(7/8) = 35.6''$

REF. APPENDIX, P. "L"

$f_{s_{ACTUAL}} = \dfrac{M_s}{A_s j d} = \dfrac{60.7\ ft\cdot k\,(12\ in/ft)}{1.20\ in^2(7/8)(35.6)} = 19.5\ ksi$

USE #7 @ 6"

$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ $\quad 19.5\ ksi < 27.3\ ksi$ (OK)

TOP STEEL

$M_s = 0.0104(7.48' + 1.63')^3 = 7.86\ ft\cdot k$

$V_s = 0.0312(7.48 + 1.63')^2 = 2.59^k$

TRY #6 @ 12" $A_s = 0.44\ in^2$

$f_s = 21.6\ ksi$ (ACI 350 2.6.7(b))

$A_{s_{TOTAL}} = \dfrac{4/3(7.86\ ft\cdot k)(12)}{21.6\ ksi(7/8)(35.6)} + \dfrac{2.59}{21.6} = 0.31\ in^2$

CLIENT	JOB NUMBER
SUN OIL	RC-0086

SUBJECT
CONCRETE TRENCH DESIGN

BASED ON	DRAWING NUMBER
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BY	CHECKED BY	APPROVED BY	DATE
M DYE	J. Schmotzl		11/2/92

$A_{s_{MIN}} = 0.0018\,bh/2 = 0.0018(12'')(3.25\,ft)(12)/2 = 0.42\,in^2$

$A_{s_{MIN}}$ GOVERNS

USE #6 @ 12" $A_s = 0.44\,in^2$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/15/92

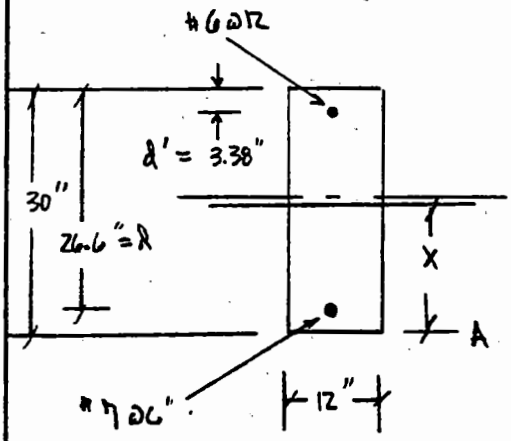
DUE TO THE SLAB BEING DESIGNED FOR FLEXURE ONLY, ANALYZE THE SLABS FOR AXIAL LOAD AND FLEXURE.

CASE 1

$M_u = 126.2\ ft\cdot k$ (SEE APPENDIX P. "L")

$V_u = 31.2^k = P_u$ (SEE APPENDIX P. "L")

$e = M_u/P_u = 126.2^{k\cdot ft}(12''/ft)/31.2^k = 48.54''$



ASSUME 3" COVER TOP & BOTTOM

$A_s = 1.20\ in^2$ $A_s' = 0.44\ in^2$

FIND THE PLASTIC CENTROID (P. 406 WANG & SALM

FORCE IN CONCRETE = $C_1 = 0.85 f_c'(A_g - A_{st})$

$C_1 = 0.85(4\ ksi)(360\ in^2 - 1.64\ in^2)$

$C_1 = 1218^k$

FORCE IN TOP STEEL = $C_3 = A_s' f_y = 0.44(60) = 26.4$

FORCE IN BOTTOM STEEL = $C_2 = A_s f_y = 1.20(60) = 72$

$$\Sigma M_A = 0;\ x = \frac{1218^k(30''/2) + 26.4^k(30'' - 3.38'') + 72.0^k(30'' - 26.6'')}{1218^k + 26.4 + 72}$$

$x = 14.60''$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
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$d'' = 14.60'' - 3.4'' = 11.20$

DUE TO LARGE ECCENTRICITY (e) ASSUME TENSION CONTROLS

DETERMINE ALLOWABLE AXIAL LOAD @ BALANCED CONDITION (P. 418 WAN

$x_b = 87d / [f_y + 87] = 87(26.6)/[60+87] = 15.74''$ (EQ 13.12.1)

$C_c = 0.85 f'_c \beta_1 x_b b = 0.85(4)(0.85)(15.74'')(12'') = 545.9^k$ (EQ 13.12.3)

$T = A_s f_y = 1.20(60) = 72^k$ (EQ 13.12.4)

CHECK TO SEE IF COMPRESSION STEEL YIELDS

$\epsilon'_s = 0.003\left(\frac{x_b - d'}{x_b}\right) = 0.003\left(\frac{15.74'' - 3.38''}{15.74''}\right) = 0.0024$ (EQ 3.6.4)

$\epsilon_y = f_y/E_s = 60/29{,}000 = 0.0021$

$\epsilon'_s \geq \epsilon_y$ COMPRESSION STEEL YIELDS

$C_s = A'_s(f_y - 0.85 f'_c) = 0.44(60 - 0.85(4)) = 24.9^k$ (EQ 13.12.5)

$P_b = C_c + C_s - T = 545.9^k + 24.9^k - 72.0^k = 498.8^k$ (EQ 13.12.6)

$M_b = P_b e_b$

$P_b e_b = C_c(d - a/2 - d'') + C_s(d - d' - d'') + Td''$ (EQ 13.12.7)

$a = \beta_1 x_b = 0.85(15.74) = 13.38''$

$P_b e_b = [545.9(26.6 - 13.38/2 - 11.20) + 24.9(26.6 - 3.38 - 11.20) + 72(11.20)]/$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
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M DYE / J. Schmohl	10/15/92

$P_b e_b = 488.4$ ft·k

$P_b = 498.8^k$ (P30)

$e_b = 488.4$ ft·k $/498.8 = 11.75''$ $\quad e > e_b$ TENSION CONTROLS

USE THE APPROXIMATE FORMULA FOR THE TENSION CONTROL CASE TO DETERMINE THE NOMINAL COMPRESSIVE STRENGTH (P_n) (FORMULA 13.14.6 P. 431 WANG & SALMON)

$$P_n = 0.85 f'_c bd \left\{ \rho'(m-1) - \rho m + (1 - e'/d) + \sqrt{(1-e'/d)^2 + 2\left[(e'/d)(\rho m - \rho'(m-1)(1-d'/d)\right]} \right\}$$

$m = f_y / 0.85 f'_c = 60/[0.85(4)] = 17.65$

$\rho = A_s/bd = 1.20/[(12)(26.6)] = 0.00376$

$\rho' = A'_s/bd = 0.44/[(12)(26.6)] = 0.00138$

$e' = e + d'' = 48.54'' + 11.20'' = 59.74''$

$P_n = 51.66^k$ (SOLVED BY PROGRAMMING EQ. IN CALCULATOR)

DUE TO INCLUDING DURABILITY COEFFICENT (1.3) AND INCREASED LOAD FACTOR FOR THE WATER (1.7), WHEN CALCULATING P_u USE ULTIMATE STRENGTH STRENGTH REDUCTION FACTORS AND DISREGARD SAFETY FACTORS FROM ACI 9.4.6

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmidt	APPROVED BY / DATE: 10/15/92

$0.10 f'_c A_g = 0.10(4\,ksi)(2.5\,ft)(12)(12") = 144^k$

$\phi = 0.7 + [(144^k - 31.2^k)/144^k]\,0.20 = 0.86$ (ACI 318 9.3.2.2 b)

NOTE: SEE APPENDIX, p. "M" FOR CHECK OF NOMINAL AXIAL LOAD STRENGTH, P_b

$\phi P_n = 0.86(51.66^k) = 44.4^k$

BY INSPECTION: NEGLECT SLENDERNESS EFFECTS

$\phi P_n > P_u$ $\quad 44.4^k > 31.2^k$ (ok)

CASE 2

USE SAME PROCEDURE AS FOR CASE 1

$M_u = 134.1\ ft\cdot k$ (SEE APPENDIX P. "L")

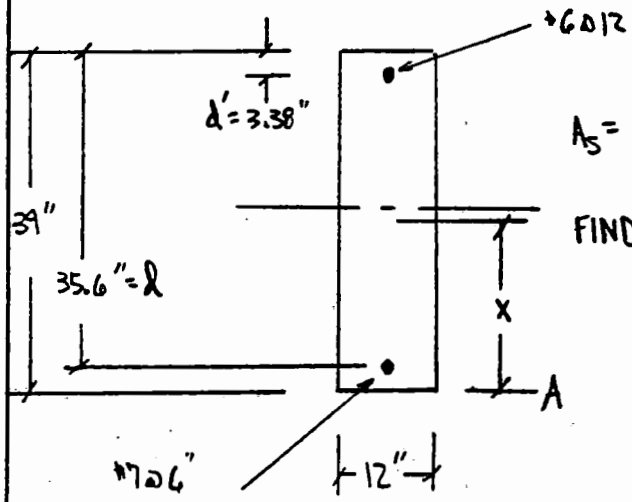
$P_n e = M_n \quad 51.66^k(48.54/12) =$

$\phi M_n = 0.86(209) = 180\ ft\cdot k$

$\phi M_n > M_u \quad 180\ ft\cdot k > 126.2\ ft\cdot k$

$P_u = V_u = 34.0^k$ (SEE APPENDIX P. "L")

$e = M_u/P_u = 3.94\ ft = 47.28"$



3" COVER TOP & BOTTOM

$A_s = 1.20\ in^2 \quad A'_s = 0.44\ in^2$

FIND PLASTIC CENTROID

$C_1 = 0.85(4)(468\ in^2 - 1.64\ in^2) = 1586^k$

$C_3 = A'_s f_y = 0.44(60) = 26.4^k$

$C_2 = A_s f_y = 1.20(60) = 72.0^k$

$\Sigma M_A = 0; \quad x = \dfrac{1586^k(39/2) + 26.4(39 - 3.38) + 72.0(39 - 35.6)}{1586 + 26.4 + 72.0}$

$x = 19.06"$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/15/92

$d'' = x - 3''(\text{cover}) - \frac{1}{2}(\#7 \text{ bar}) = 19.62'' - 3'' - \frac{1}{2}(7/8) = 15.62''$

DUE TO LARGE ECCENTRICITY (e) ASSUME TENSION CONTROLS

FOLLOW THE SAME PROCEDURE THAT WAS USED FOR CASE 1

$x_b = 87(d)/[87 + f_y] = 21.07''$

$C_c = 0.85 f'_c \beta_1 x_b b = 0.85(4)(0.85)(21.07)(12) = 730.7^k$

$T = A_s f_y = 1.20(60) = 72.0^k$

CHECK COMPRESSION STEEL

$\epsilon'_s = 0.003\left(\frac{21.07 - 3.38}{21.07}\right) = 0.0025$

$\epsilon_y = f_y/E_s = 60/29{,}000 = 0.0021$

$\epsilon'_s \geq \epsilon_y$ COMPRESSION STEEL YIELDS

$C_s = A'_s(f_y - 0.85 f'_c) = 0.44(60 - 0.85(4)) = 24.9^k$

$P_b = C_c + C_s - T = 730.7^k + 24.9^k - 72^k = 683.6^k$

$M_b = P_b e_b$

$P_b e_b = C_c(d - a/2 - d'') + C_s(d - d' - d'') + Td''$ $\quad a = \beta_1 x_b = 17.91''$

$P_b e_b = [730.7(35.6 - 17.91/2 - 15.62) + 24.9(35.6 - 3.38 - 15.62) + 72(15.62)]/(1$

$P_b e_b = 799.5$ ft·K

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmehl	APPROVED BY / DATE: 10/15/92

$P_b e_b = 799.5$ ft·k $P_b = 683.6^k$

$e_b = 799.5$ ft·k / 683.6 = 14.03" $e > e_b$ TENSION CONTROLS

$m = 17.65$

$\rho = 1.20/[(12)(35.6)] = 0.00281$

$\rho' = 0.44/[(12)(35.6)] = 0.00103$

$e' = e + d'' = 47.28'' + 15.62'' = 62.90''$

SOLVING EQ. ON P. 31 YIELDS

$P_n = 83.2^k$ $0.10 f'_c A_g = 0.1(4\text{ ksi})(12'')(3.25\text{ ft})(12) = 187.2^k$

$\phi = 0.7 + [(187.2^k - 34.0^k)/187.2^k]\,0.20 = 0.86$

$\phi P_n = 0.86(83.2^k) = 71.6^k$

$\phi P_n > P_u$ $71.6^k > 34.0^k$ (ok) BY INSPECTION NEGLECT SLENDERNE EFFECTS

$M_n = P_n e$

$M_n = 83.2^k(47.28'') = 327.8$ ft·k

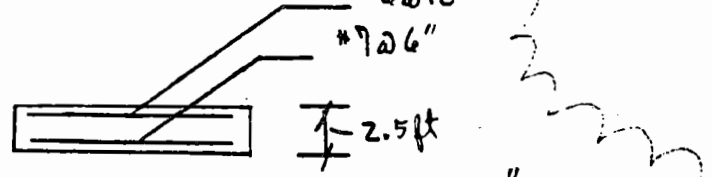
$\phi M_n = 0.86(327.8) = 281.9$ ft·k

$\phi M_n > M_u$ 281.9 ft·k > 139.1 ft·k (ok)

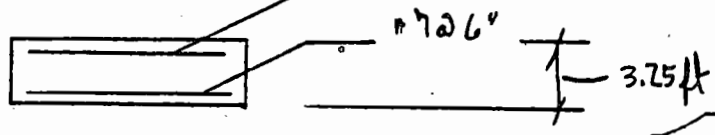
SUMMARY

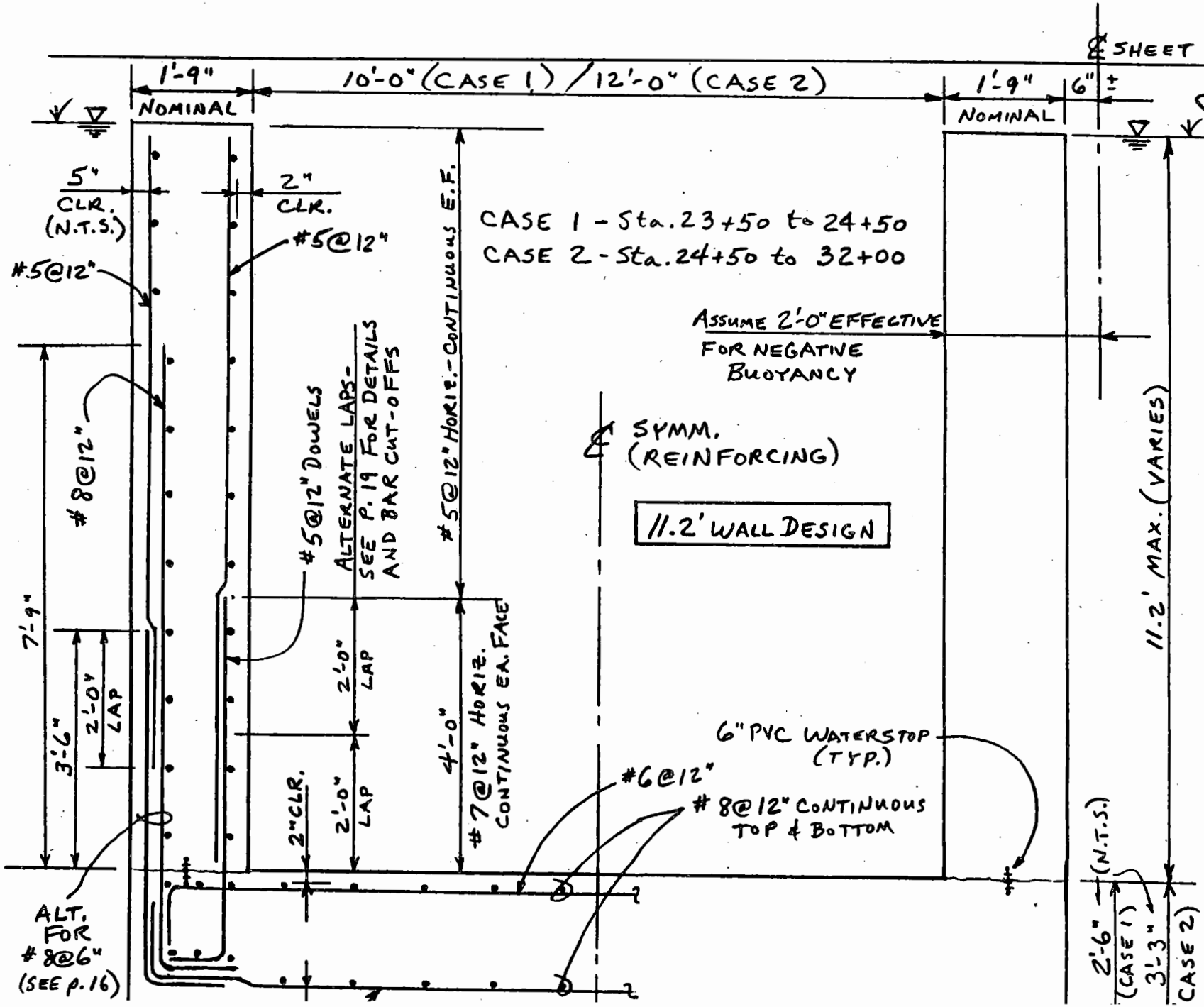
11.2 ft WALL

CASE 1
STA 0+00 - 24+50



CASE 2
STA 24+50 - 35+34.52




1'-9" NOMINAL
10'-0" (CASE 1) / 12'-0" (CASE 2)
1'-9" NOMINAL
6" ±
℄ SHEET PILE
5" CLR. (N.T.S.)
2" CLR.
#5@12"
#5@12"
CASE 1 - Sta. 23+50 to 24+50
CASE 2 - Sta. 24+50 to 32+00
#5@12" HORIZ. - CONTINUOUS E.F.
ASSUME 2'-0" EFFECTIVE FOR NEGATIVE BUOYANCY
#8@12"
#5@12" DOWELS
ALTERNATE LAPS - SEE P. 19 FOR DETAILS AND BAR CUT-OFFS
℄ SYMM. (REINFORCING)
11.2' WALL DESIGN
11.2' MAX. (VARIES)
7'-9"
3'-6"
2'-0" LAP
2'-0" LAP
2'-0" LAP
4'-0"
#7@12" HORIZ. CONTINUOUS EA. FACE
2" CLR.
6" PVC WATERSTOP (TYP.)
#6@12"
#8@12" CONTINUOUS TOP & BOTTOM
ALT. FOR #8@6" (SEE p. 16)
2'-6" (CASE 1)
3'-3" (CASE 2)
(N.T.S.)
CLIENT Sun Oil
SUBJECT Concrete Trench Design
BY J. Schmohl
CHECKED BY R. Duncan
APPROVED BY
DATE 12/2/92
BASED ON
DRAWING NUMBER
JOB NUMBER RC-0086

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/16/92

10 ft WALL DESIGN

USE THE SAME WALL THICKNESS AS FOR THE 11.2 ft WALL DUE TO BUOYANCY CONSIDERATIONS

BY INSPECTION, NEGLECT SHEAR CALCULATIONS (SAME WALL THICKNESS AS 11.2 ft WALL AND LESS LOAD)

$M = [166x^2 + 6.5x^3 + 10.4x^3]/1000$ (FORMULA P. 22 W/O LOAD FACTOR

$M = [166(10ft)^2 + 6.5(10ft)^3 + 10.4(10ft)^3]/1000$

$M = 33.5$ ft·k

ASSUME #8 BAR

$d = 18'' - 2''(\text{cover}) - 1/2(1'') = 15.5''$

$$A_{s\,REQ'D} = \frac{M}{f_s j d} = \frac{33.5\ ft\cdot k\ (12in/ft)}{24\ ksi\ (7/8)(15.5'')} = 1.24\ in^2$$

TRY USING #7 @ 6" $A_s = 1.20\ in^2$ $d = 18'' - 2''(\text{cover}) - 1/2(7/8) = 15.6''$

FIG 2.6.7(b) ACI 350 $f_s = 27.3$ ksi

$$A_{s\,REQ} = \frac{M}{f_s j d} = \frac{33.5\ ft\cdot k\ (12in/ft)}{27.3\ ksi\ (7/8)(15.6'')} = 1.08\ in^2$$

$A_{s\,PROVIDED} = 1.20\ in^2 > A_{s\,REQ'D} = 1.08\ in^2$ (OK)

Use #7@6" @ EXT. BASE OF WALL

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	
BY M DYE / J. Schmohl — CHECKED BY R DUNCAN	APPROVED BY — DATE 10/22/92

10 ft WALL

$M_{200/f_y} = 16.55'^k$ (SAME WALL THICKNESS AS 11.2 ft WALL ∴ M_{200/f_y} IS THE SAME)

DISTANCE DOWN WALL WHERE M_{200/f_y} OCCURS = 7.52 ft (SEE 11.2 ft WALL, p. 13)

DISTANCE DOWN WALL WHERE THE WALL CAN BE DESIGNED FOR $4/3\ M_{ACT}$ = 6.67' (SEE 11.2 ft WALL, p. 13)

$M_{0.0018A_g/2}$ = 4.60' (" ")

See Next page for Continuation of Ext. Face Reinf.

Interior Face of Wall - Use same dowel lengths, bar sizes and splices as shown on p. 19 for 11.2' high wall.

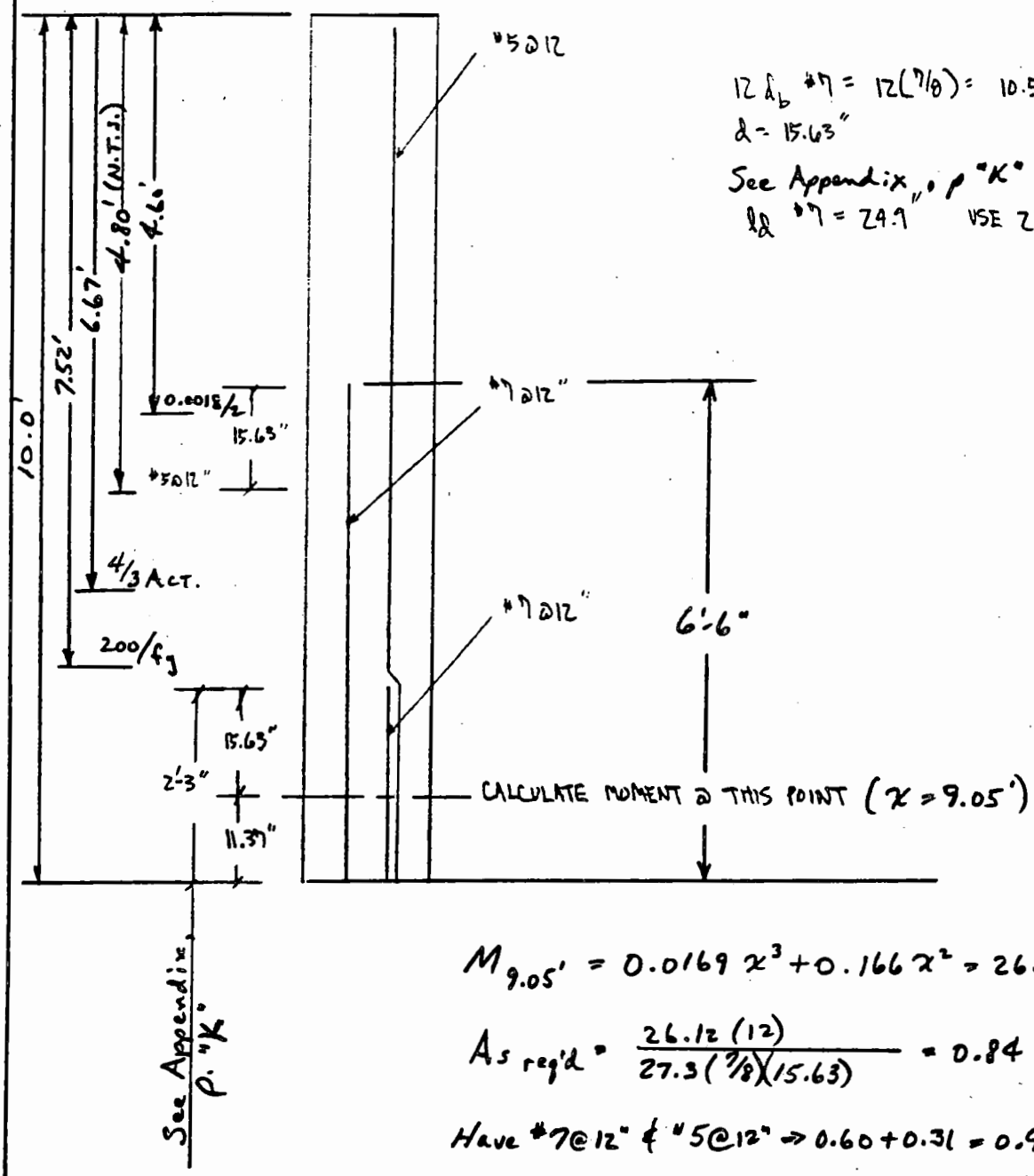
CLIENT	JOB NUMBER
SUN OIL	RC-0086

SUBJECT: CONCRETE TRENCH DESIGN

BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	

BY	CHECKED BY	APPROVED BY	DATE
M. DYE / J. Schmohl	TR DUNCAN		10/16/92

FROM PAGE 16, #5 @ 12" CAN BE USED 4.80 ft FROM THE TOP OF THE WALL



$12 d_b$ #7 = 12(7/8) = 10.5

d = 15.63"

See Appendix, p "K"

l_d #7 = 29.9" USE 2'-3"

$$M_{9.05'} = 0.0169\,x^3 + 0.166\,x^2 = 26.12'^k$$

$$A_{s\ req'd} = \frac{26.12\,(12)}{27.3\,(7/8)(15.63)} = 0.84\ in^2$$

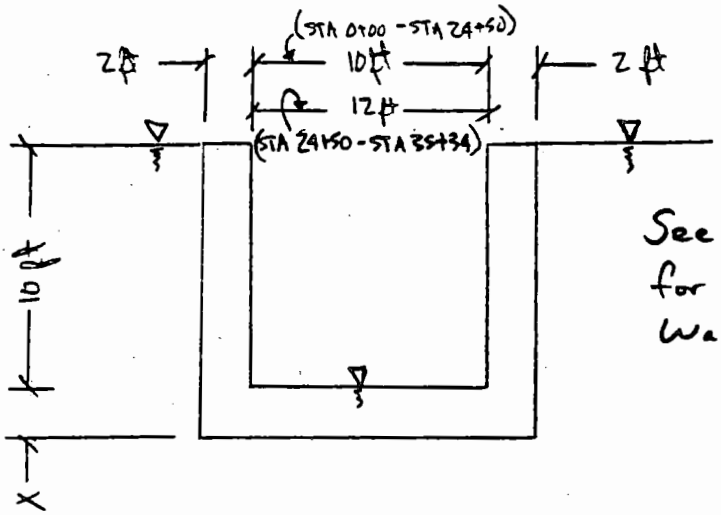
Have #7@12" & #5@12" ⇒ 0.60 + 0.31 = 0.91 in^2

OK

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/16/92

DESIGN BOTTOM SLAB

SEE NOTES ON P. 20 CALCS



See p. 49 & 119 for Locations of 10' High Wall Design.

CASE 1 STA 0+00 - STA 24+50 ; 10 ft WIDE

$\uparrow \Sigma F = \downarrow \Sigma F$ (USE A SAFETY FACTOR = 1.0)

$$62.4\ pcf\,(1\,ft)(14\,ft)(10\,ft + x)/1000 = 2\,ft(10\,ft)(1\,ft)(.15\ kcf)(2\ WALLS) + (14\,ft)(1\,ft)(x)(.15\ kcf)$$

$$0.87x + 8.73 = 6.00 + 2.1x$$

$$x = 2.22\ ft$$

USE 2'-3" SLAB

CASE 2 STA 24+50 - STA 35+34 ; 12 ft WIDE

$$62.4\ pcf\,(1\,ft)(16\,ft)(10\,ft + x)/1000 = 2\,ft(10\,ft)(1\,ft)(.15\ kcf)(2\ WALLS) + (16\,ft)(1\,ft)(x)(.15\ kcf)$$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmohl — CHECKED BY: TR DUNCAN	APPROVED BY — DATE: 10/16/92

$$1.00x + 9.98 = 6.00 + 2.4x$$

$$x = 2.84 \text{ ft}$$

USE 3'-0" SLAB

CALCULATE THE MOMENT ON THE BASE SLAB

CASE 1

LOAD ACTING ON SLAB = WEIGHT WALLS / TRENCH WIDTH

$= 6.00^k / 14 \text{ ft}$

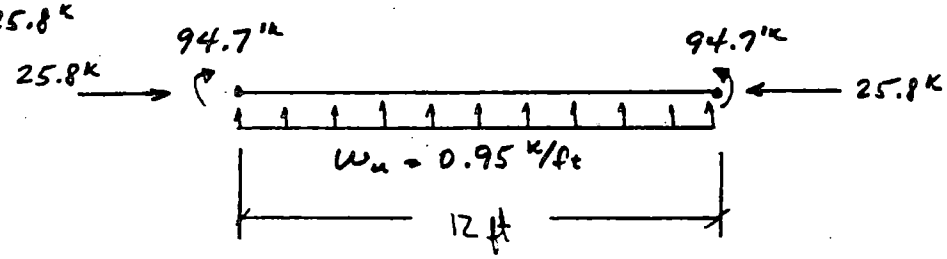
$w_s = 0.43 \text{ k/ft}$

ACI 350 2.6.5

$w_u = 0.43 \text{ k/ft}(1.3)(1.7) = 0.95 \text{ k/ft}$

(ACI 350 2.6.5(a))

Appendix, p. "L"
$M_u = 94.7'^k$
$P_u = 25.8^k$



$$M_{s_{POS}} = w_s l^2/8 = 0.43 \text{ k/ft}(12 \text{ ft})^2/8 = 7.74 \text{ ft}\cdot\text{k}$$

$$M_{u_{POS}} = w_u l^2/8 = 0.95 \text{ k/ft}(12 \text{ ft})^2/8 = 17.11 \text{ ft}\cdot\text{k}$$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmohl — CHECKED BY: R DUNCAN	APPROVED BY / DATE: 10/16/92

CASE 2

LOAD ACTING ON SLAB = WEIGHT WALLS / TRENCH WIDTH

$= 6.00^k / 16\ ft$

$w_s = 0.38\ k/ft$

$w_u = 0.38\ k/ft\ (1.3)(1.7) = 0.83\ k/ft$

$M_{s_{pos}} = w_s l^2/8 = 0.38\ k/ft\ (14\ ft)^2/8 = 9.31\ ft\cdot k$

$M_{u_{pos}} = w_u l^2/8 = 0.83\ k/ft\ (14\ ft)^2/8 = 20.34\ ft\cdot k$

DESIGN THE BASE SLABS ON FLEXURE

CASE 1

BOTTOM STEEL

$M_u = 94.7\ ft\cdot k$ (p. 40)

$d = 2.25\ ft - 3''(\text{cover}) - 1/2\,(1'') = 23.5''$

$R_n = M_u/\phi b d^2 = \dfrac{94.7\ ft\cdot k\,(12{,}000)}{0.9\,(12'')(23.5'')^2} = 191\ psi$

$\rho_{req'd} = 0.0033$

$\rho_{min} = 200/f_y$ or 1.33ρ or $0.0018/2$

$\rho_{min} = 0.0033$ or $1.33(0.0033) = 0.0044$

USE $\rho = 0.0033$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
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$A_{s_{REQ'D}} = \rho b d = 0.0033(12)(23.5) = 0.93\ in^2$

TRY #8 @ 9" $A_s = 1.05\ in^2$

CHECK CRACKING

$f_{s_{ALLOW}} = 23.8^{ksi}$ (ACI 350 FIG 2.47(b)) (Ref. also p."E" of Appendix

$f_{s_{ACTUAL}} = \dfrac{M_s}{A_s j d} = \dfrac{42.9\ ft\text{-}k(12\ in/ft)}{1.05\ (7/8)(23.5)} = 23.8\ ksi$

$f_{s_{ACTUAL}} \le f_{s_{ALLOW}}$ $23.8\ ksi \le 23.8\ ksi$ (OK) USE #8@9"

TOP STEEL

$M_s = 0.0104(7.48' + 1.13')^3 = 6.64'^k$

$V_s = 0.0312(7.48 + 1.13)^2 = 2.31^k$

Try #5 @ 9" $A_s = 0.41\ in^2$

$f_{s_{ALLOW.}} = 25.1^{ksi}$ (See Appendix, p."E")

$A_{s_{TOTAL}} = \dfrac{4/3(6.64'^k)(12''/')}{25.1^{ksi}(7/8)(23.5'')} + \dfrac{2.31^k}{25.1^{ksi}} = 0.21 + 0.09 = 0.30\ in^2$

$A_{s_{min}} = 0.0018(12)(27)/2 = 0.29\ in^2$ CONTROLS

Use #5@9" = 0.41 in²

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmoll — CHECKED BY: R DUNCAN	APPROVED BY — DATE: 10/16/92

CASE 2

BOTTOM STEEL

$M_u = 101.4$ ft·k

$d = 36'' - 3''(\text{cover}) - \frac{1}{2}(1'') = 32.5''$

$R_n = M_u / \phi b d^2 = \frac{101.4 \text{ ft·k } (12{,}000)}{0.9\,(12)(32.5)^2} = 107$ psi

$\rho_{req'd} = 0.0018$ (See EQ, p.25)

$\rho_{min} = 1.33\rho$ or $0.0018 A_g/2$ or $200/f_y$

$\rho = 1.33(0.0018) = 0.0024$ ← GOVERNS

$A_s = \rho b d = 0.0024(12)(32.5) = 0.94 \text{ in}^2$

TRY #8 @ 9" $A_s = 1.05 \text{ in}^2$

CHECK CRACKING

$d = 36'' - 3''(\text{cover}) - \frac{1}{2}(1'') = 32.5$

$f_{s_{ALLOW}} = 23.8$ ksi (#8 @ 9") (ACI 350 FIG 2.6.7(b))

$f_{s_{ACTUAL}} = \frac{M_s}{A_s j d} = \frac{45.9 \text{ ft·k } (12''/\text{ft})}{1.05 \text{ in}^2 (7/8)(32.5)} = 18.5$ ksi

$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ 18.5 ksi < 23.8 ksi (ok)

USE #8 @ 9"

CLIENT Sun Oil		JOB NUMBER	
SUBJECT Concrete Trench Design			
BASED ON		DRAWING NUMBER	
BY J. Schmohl	CHECKED BY R DUNCAN	APPROVED BY	DATE 11/4/92

TOP STEEL

$$M_s = 0.0104\,(7.48' + 1.50')^3 = 7.53'^{K}$$

$$V_s = 0.0312\,(7.48 + 1.50')^2 = 2.52^{K}$$

Try #5 @ 9" $A_s = 0.41\ in^2$

$f_{s\ ALLOW} = 25.1^{ksi}$ (Appendix, p "E")

$$A_{s\ TOTAL} = \frac{4/3\,(7.53'^{K})(12''/')}{25.1^{ksi}\,(7/8)(32.5")} + \frac{2.52^{K}}{25.1^{ksi}} = 0.17 + 0.10 = 0.27\ in^2$$

$$A_{s\ min} = 0.0018\,(12)(36)/2 = 0.39\ in^2 \longleftarrow \text{CONTROLS}$$

Use #5 @ 9" $\Rightarrow A_s = 0.41\ in^2$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmohl — CHECKED BY: R DUNCAN	APPROVED BY — DATE: 10/17/92

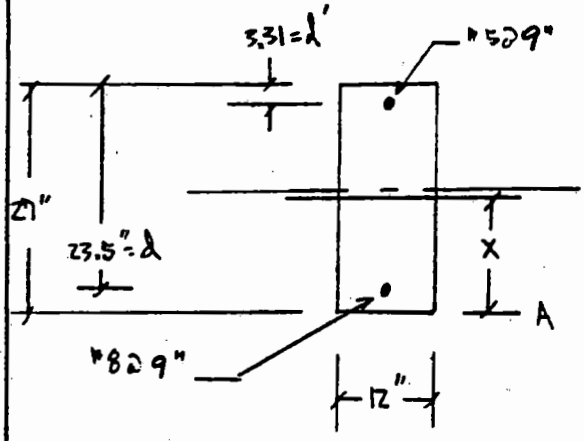
ANALYZE THE SLAB FOR COMBINED BENDING AND AXIAL LOAD

CASE 1

$M_u = 94.7\ ft\cdot k$
$P_u = 25.8^k$

See Appendix, p. "L"

$e = M_u/P_u = 94.7\ ft\cdot k\ (12in/ft)/25.8^k = 44.0''$



3" COVER TOP & BOTTOM

$A_s = 1.05\ in^2 \quad A_s' = 0.41\ in^2$

FIND THE PLASTIC CENTROID

$C_1 = 0.85 f'_c (A_g - A_{st})$

$C_1 = 0.85(4)\left((27)(12) - (1.05 + 0.41)\right) = 1097^k$

$C_3 = A_s' f_y = 0.41(60) = 24.6^k$

$C_2 = A_s f_y = 1.05(60) = 63.0^k$

$\Sigma M_A = 0; \quad X = \dfrac{1097(27/2) + 24.6^k(27 - 3.31) + 63(27 - 23.5)}{1097 + 24.6 + 63.0}$

$X = 13.18''$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	
BY / CHECKED BY	APPROVED BY / DATE
M DYE / J. Schmoll / R DUNCAN	10/17/92

$d'' = 13.18'' - (27'' - 23.5'') = 9.68''$

DUE TO LARGE ECCENTRICITY (e) ASSUME TENSION CONTROLS

DETERMINE ALLOWABLE AXIAL LOAD @ BALANCED CONDITION

$x_b = 87d/[87+f_y] = 87(23.5)/[87+60] = 13.91''$

$C_c = 0.85 f'_c a b \qquad a = \beta_1 x_b = 0.85(13.91) = 11.82''$

$C_c = 0.85(4)(11.82)(12) = 482^k$

$T = A_s f_y = 1.05(60) = 63^k$

CHECK TO SEE IF COMPRESSION STEEL YIELDS

$\epsilon'_s = 0.003\left(\frac{x_b - d'}{x_b}\right) = 0.003\left(\frac{13.91 - 3.31}{13.91}\right) = 0.0023$

$\epsilon_y = f_y/E_s = 60/29{,}000 = 0.0021$

$\epsilon'_s > \epsilon_y$ COMPRESSION STEEL YIELDS

$C_s = A'_s(f_y - 0.85 f'_c) = 0.41(60 - 0.85(4)) = 23.2^k$

$P_b = C_c + C_s - T = 482^k + 23.2^k - 63^k = 442.2^k$

$M_b = P_b e_b$

$P_b e_b = C_c(d - a/2 - d'') + C_s(d - d' - d'') + Td''$

$P_b e_b = [482(23.5 - 11.82/2 - 9.68) + 23.2(23.5 - 3.31 - 9.68) + 63(9.68'')]$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmohl — CHECKED BY: R DUNCAN	APPROVED BY — DATE: 10/17/92

$P_b e_b = 388.9$ 'K

$P_b = 442.2^k \quad \therefore \quad e_b = 10.55''$

$e > e_b \quad 44.0'' > 10.55''$ (TENSION CONTROLS)

CALCULATE P_n (EQ 13.14.6, P 431, WANG & SALMON)

$m = 17.65$

$\rho = A_s/bd = 1.05/((12)(23.5)) = 0.0037$

$\rho' = A_s'/bd = 0.41/((12)(23.5)) = 0.0015$

$e' = e + d'' = 44.0'' + 9.68'' = 53.68$

SOLVING EQ. ON P. 31 YIELDS

$P_n = 43.4^K$ (FROM PROGRAM IN CALCULATOR)

SEE NOTE BOTTOM OF P. 31

$0.10 f'_c A_g = 0.10(4.0)(12)(27) = 130^K$

$\phi = 0.70 + [(130 - 25.8)/130](0.20) = 0.86$

$\phi P_n = 0.86(43.4^K) = 37.3^K$

$\phi P_n \geq P_u \quad 37.3^K > 25.8^K$ (ok) BY INSPECTION; NEGLECT SLENDERN EFFECTS

$P_n e = M_n$

$M_n = 43.4^K(44.0'')(1'/12'') = 159.1$ ft·k

$\phi M_n \geq M_u \quad 0.86(159.1) \geq 94.7$ (ok)

136.8

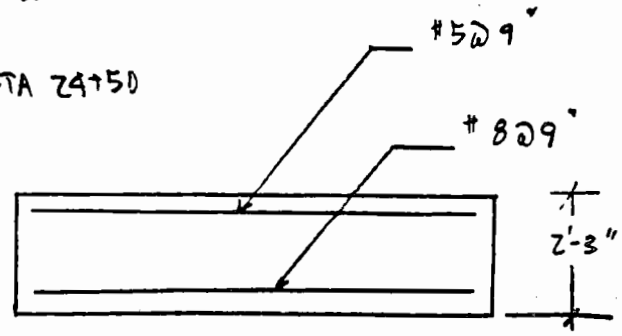
CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	
BY M DYE / J. Schmohl — CHECKED BY R DUNCAN	APPROVED BY — DATE 10/19/92

SUMMARY

10 ft WALL BASE SLABS

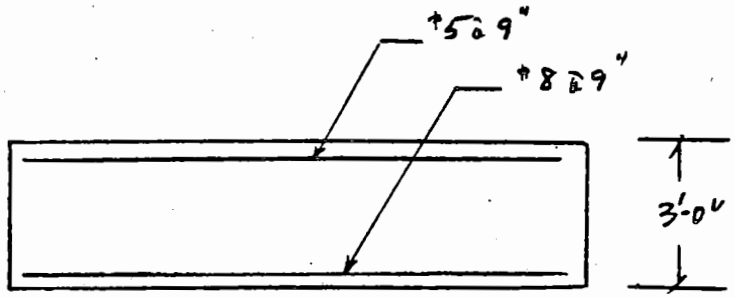
CASE 1:

STA 0+00 - STA 24+50



CASE 2:

STA 24+50 - STA 35+34.52



NOTE: By observation of bottom slab designs for Case 1 & Case 2 for 11.2' wall height (p. 32 & p. 34, respectively when a thicker bottom slab is used with the same reinforcing, the bottom slab design for the thicker slab will be more conservative than the design for the thinner slab. Therefore, Case 2 above is O.K. by inspection.

CLIENT Sun Oil		JOB NUMBER RC-0086	
SUBJECT Concrete Trench Design			
BASED ON		DRAWING NUMBER	
BY J. Schmohl	CHECKED BY R DUNCAN	APPROVED BY	DATE 12/10/92

Check Trench Sections from Sta 0+00 to Sta. 4+50

for Negative Buoyancy without (6" add'l conc. for) sheet piles

Use 1'-9" wall thickness throughout this section per discussi with Roy Duncan 12/9/92. Bottom slab is 2'-3" thick.

Maximum ground water elevation for design this section of trench is EL. 16.0'. Deepest trench section is at Sta. 4+50

Top of Wall = Assumed Groundwater Elevation = EL. 16.0'

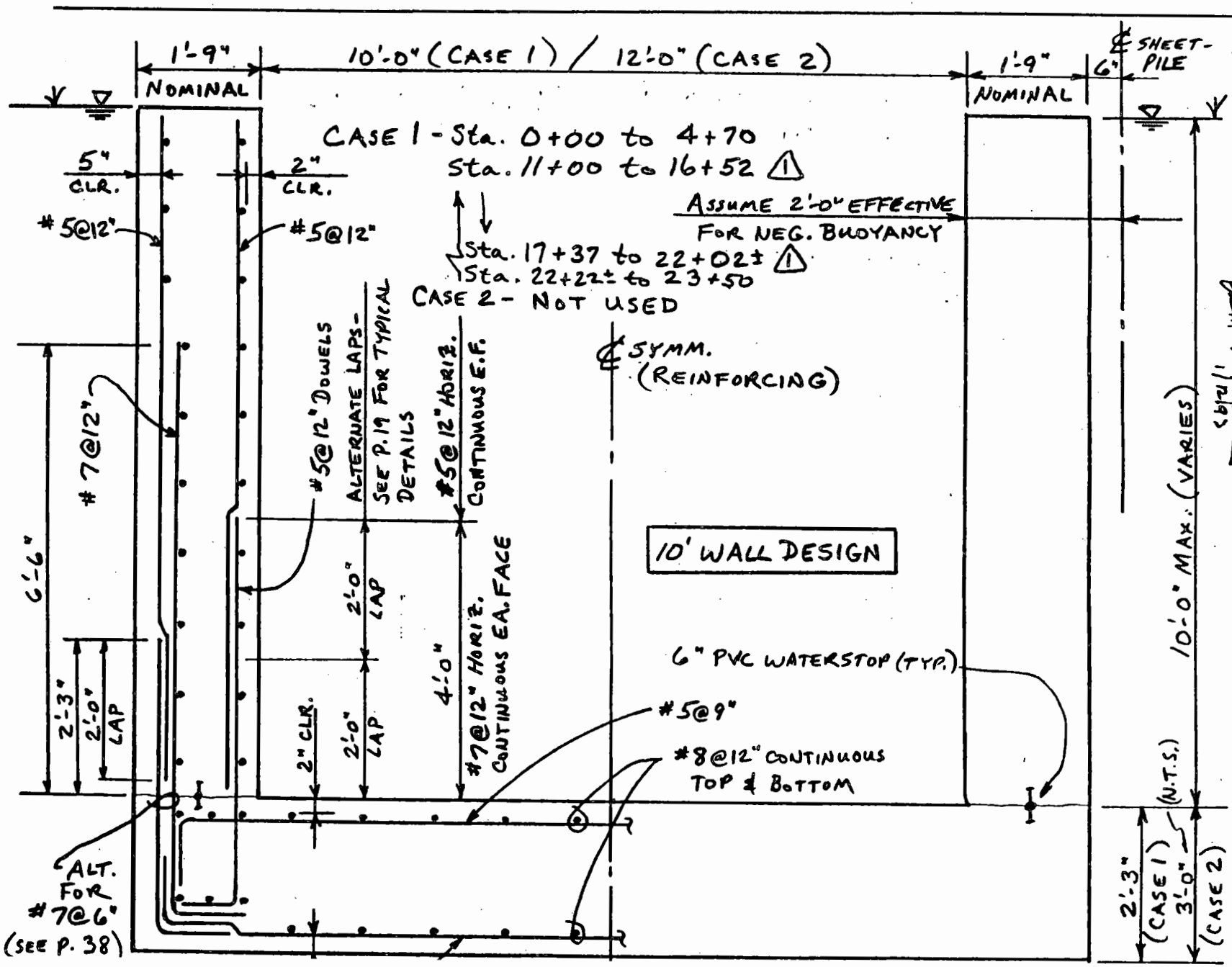
Top of Bottom Slab @ Sta. 4+50 = EL. 8.67'

Volume of Water Displaced:

Depth = 16.0' − 8.67' + 2.25' = 9.58'
× Width = 10' + 2 (1.75') = × 13.50'
129.33 s.f.
× 62.4 pcf × 1' of tr
↑ 8,070 Lb /ft of tren

Concrete:
Slab: 13.50' × 2.25' = 30.38 s.f.
Walls: 2 × 1.75' × 7.33' = 25.65
56.03 s.f
× 150 pcf × 1' of trench
8,405 Lb./ft of trench

S.F. = 1.04 > 1.00 OK See p. 10



CLIENT: Sun Oil			JOB NUMBER: RC-0086
SUBJECT: Concrete Trench Design			
BASED ON			DRAWING NUMBER
BY: J. Schmoll	CHECKED BY: R. Duncan	APPROVED BY	DATE: 12/2/92
			REV. △1

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/13/92

8 ft WALL

WALL DESIGN

USE THE SAME WALL THICKNESS AS FOR THE 11.2 ft WALL DUE TO BUOYANCY CONSIDERATIONS

BY INSPECTION, NEGLECT SHEAR CALCULATIONS (SAME WALL THICK AS THE TALLER WALL AND LESS LOAD)

$M = [166x^2 + 6.5x^3 + 10.4x^3]/1000$ (FORMULA P. 22 W/O LOAD FACTORS)

$M = [166(8)^2 + 6.5(8)^3 + 10.4(8)^3]/1000 = 19.3$ ft·k

$d = 18'' - 2''(\text{cover}) - \frac{1}{2}(1'') = 15.5''$

ASSUME #8 bar

$$A_{s_{REQ'D}} = \frac{M}{f_s j d} = \frac{19.3\ \text{ft·k}\ (12\text{in}/\text{ft})}{24\ \text{ksi}\ (7/8)(15.5'')} = 0.71\ \text{in}^2$$

TRY #6 @ 6" $A_s = 0.88\ \text{in}^2$ $f_s = 27.3$ ksi (ACI 350 FIG 2.6.7(b))

$d = 16'' - \frac{1}{2}(6/8) = 15.63''$ $f_{s_{ACTUAL}} = \frac{M}{A_s j d} = \frac{19.3(12)}{0.88(7/8)(15.63)} = 19.2$ ksi

$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ 19.2 ksi < 27.3 ksi (OK)

Use #6 @ 6" @ EXT. BASE OF WALL

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmoll — CHECKED BY: R DUNCAN	APPROVED BY — DATE: 10/22/92

8 ft WALL

M_{200/f_y} = 16.55 ft·k (SAME WALL THICKNESS AS 11.2 ft WALL ∴ M_{200/f_y} SAME)

DISTANCE DOWN WALL WHERE M_{200/f_y} OCCURS = 7.52 ft (SEE 11.2 ft WALL, p.13)

DISTANCE DOWN WALL WHERE THE WALL CAN BE DESIGNED FOR $4/3\ M_{ACT}$ = 6.67 ft (SEE 11.2 ft WALL, p.13)

$M_{0.0018 A_g/2}$ = 4.60' (" ")

Reinforcing Minimums:

$A_{s\ 200/f_y} = 0.0033(12")(15.6") = 0.62\ in^2$

$A_{s\ 0.0018 A_g/2} = 0.0018(12)(18)/2 = 0.19\ in^2$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
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THEORETICAL DISTANCE DOWN FROM TOP OF WALL WHERE #5 @ 12" CAN BE USED = 4.80 ft

THEORETICAL DISTANCE DOWN FROM TOP OF WALL WHERE #5 @ 12" AND #6 @ 12" SATISFY (0.44 + 0.31 = 0.75) is BELOW M_{200/f_y} Point (0.

$f_{s_{ALLOW}} = 27.3$ ksi (ACI 350 FIG 26.7(b)) (bars @ 6" o.c.)

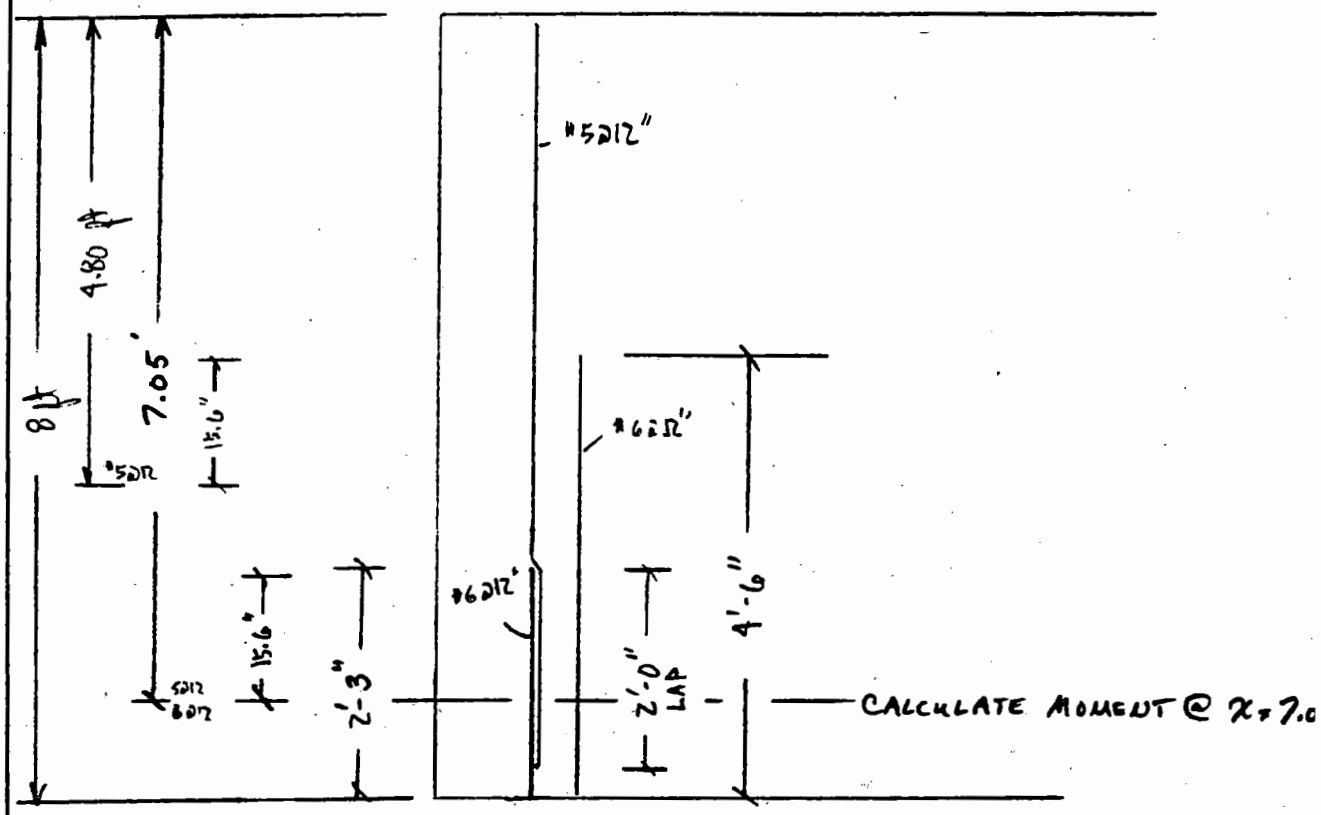
Try Moment @ $x = 7.05'$ down from top of wall (theoretical cut-off point for #6 dowel from next page).

$$M_{7.05'} = 0.0169\,x^3 + 0.166\,x^2 = 14.17'^{K}$$

#6 @ 12 & #5 @

$$A_s = \frac{M_{4/3\,ACT.}}{f_s j d} = \frac{4/3\,(14.17)(12)}{27.3\,(7/8)(15.6)} = 0.61\ in^2 < 0.75\ in$$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	
BY M DYE / J. Schmohl — CHECKED BY R DUNCAN	APPROVED BY — DATE 10/22/92

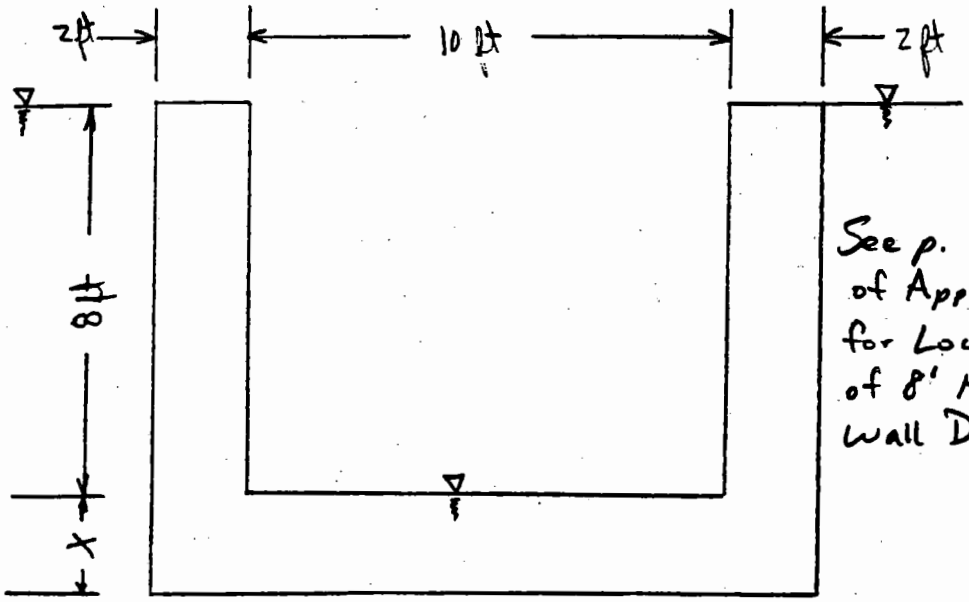


Ref. p. 38 for locations of moments for minimum reinforcing (per ACI 318-10.5).

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/15/92

DESIGN BOTTOM SLAB

SEE NOTES ON P. 20 CALCS



See p. "D" of Appendix for Locations of 8' High Wall Design

$\uparrow \Sigma F = \downarrow \Sigma F$ (USE A SAFETY FACTOR = 1.0)

$$62.4\,pcf\,(14\,ft)(1\,ft)(8\,ft + x)/1000 = 2\,WALLS\,(2\,ft)(8\,ft)(1\,ft)(.15\,kcf) + (14\,ft)(x)(1\,ft)(.15\,kcf)$$

$$0.87x + 6.99 = 4.80 + 2.1x$$

$$x = 1.78\,ft$$

USE 2'-0" SLAB

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmoll — CHECKED BY: R DUNCAN	APPROVED BY: — DATE: 10/15/92

Calculate Flexural Reinforcing for Base Slab:

$M_u = 55.5^{'k}$
$P_u = 18.6^k$
} See Appendix, p. "L"

LOAD ACTING ON SLAB = WEIGHT OF WALLS / TRENCH WIDTH

$= 4.8^k / 14\,ft = 0.34\,k/ft$

LOAD $= 1.3(1.7)(0.34\,k/ft) = 0.75\,k/ft$

M_{POS} SERVICE $= w_s l^2/8 = 0.34\,k/ft\,(12\,ft)^2/8 = 6.12\,ft\cdot k = M_s$

M_{POS} FACTORED $= w_u l^2/8 = 0.75\,k/ft\,(12\,ft)^2/8 = 13.5\,ft\cdot k = M_u$

DESIGN THE BASE SLAB BASED UPON FLEXURE

BOTTOM STEEL

$d = 24'' - 3''(\text{cover}) - \tfrac{1}{2}(1'') = 20.5''$

ASSUME #8 BAR

$R_n = M_u/\phi b d^2 = \dfrac{55.5\,ft\cdot k\,(12{,}000)}{0.9(12)(20.5)^2} = 147\,psi$

$\rho = 0.0025$

$\rho_{min} = 200/f_y$ OR $1.33\,\rho$ OR $0.0018\,A_g/2$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE STRENGTH DESIGN	DRAWING NUMBER
BY: M DYE / J. Schmoll — CHECKED BY: R DUNCAN	APPROVED BY — DATE: 10/15/92

$1.33(0.0025) = 0.0033 \longleftarrow$ GOVERNS

$A_s = \rho b d = 0.0033(12)(20.5") = 0.81 \text{ in}^2$

TRY #6 @ 6" $A_s = 0.88 \text{ in}^2$

CHECK CRACKING

USE ACI 350 ALTERNATE DESIGN METHOD ; $z = 115$; $d = 24" - 3"$ (cover) $- \frac{1}{2}($

FIG. 2.6.7 (b) ACI 350 $f_s = 27.3$ ksi for #6 @ 6"

$$f_{s_{ACTUAL}} = \frac{M_s}{A_s j d} = \frac{25.1 \text{ ft}\cdot\text{k}(12)}{0.88(7/8)(20.6)}$$

$f_{s_{ACTUAL}} = 19.0$ ksi

$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ 19.0 ksi < 27.3 ksi (ok)

USE #6 @ 6"

TOP STEEL

$M_s = 0.0104(7.48' + 1.0')^3 = 6.34^{'k}$

$V_s = 0.0312(7.48' + 1.0')^2 = 2.24^k$

Try #6@12" $A_s = 0.44 \text{ in}^2$ $f_{s_{ALLOW.}} = 21.6^{ksi}$

$$A_{s_{TOTAL}} = \frac{4/3(6.34^{'k})(12"/')}{21.6^{ksi}(7/8)(20.6")} + \frac{2.24^k}{21.6^{ksi}} = 0.26 + 0.10 = 0.36$$

$A_{s_{min}} = 0.0018(12")(24")/2 = 0.26$ CONTROLS

use #6@12" = 0.44 in^2

CLIENT	JOB NUMBER
SUN OIL	RC-0086

SUBJECT: CONCRETE TRENCH DESIGN

BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	

BY	CHECKED BY	APPROVED BY	DATE
M DYE / J. Schmohl	R DUNCAN		10/15/92

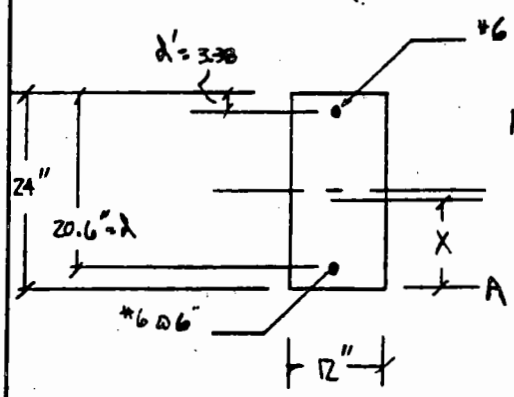
ANALYZE THE SLAB FOR COMBINED BENDING AND AXIAL LOAD

$M_u = 55.5$ ft-k
$P_u = 18.6$ k

See Appendix. p. "L"

$e = M_u / P_u = 55.5(12)/18.6 = 35.8''$

3" COVER TOP & BOTTOM



$A_s = 0.88$ in^2 $A'_s = 0.44$ in^2

FIND THE PLASTIC CENTROID

$C_1 = 0.85 f'_c (A_g - A_{st})$

$C_1 = 0.85(4)(12(24) - 1.32) = 975.$ k

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SUN OIL	RC-0086
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FORCE IN TOP STEEL $= C_3 = A_s' f_y = 0.44(60) = 26.4^k$

FORCE IN BOTTOM STEEL $= C_2 = A_s f_y = 0.88(60) = 52.8^k$

$$\Sigma M_A = 0; \quad x = \frac{975.^k(24/2) + 26.4^k(24-3.38) + 52.8^k(24-20.6)}{975. + 26.4 + 52.8}$$

$$x = 11.79''$$

$$d'' = 11.79'' - 3.38'' = 8.41''$$

DUE TO LARGE ECCENTRICITY (e) ASSUME TENSION CONTROLS

DETERMINE ALLOWABLE AXIAL LOAD @ BALANCED CONDITION

$$x_b = 87d/[f_y + 87] = 87(20.6)/[60+87] = 12.19''$$

$$C_c = 0.85 f'_c \beta_1 x_b b = 0.85(4)(0.85)(12.19)(12) = 422.7^k$$

$$T = A_s f_y = 0.88(60) = 52.8^k$$

CHECK TO SEE IF COMPRESSION STEEL YIELDS

$$\epsilon_s' = 0.003\left(\frac{x_b - d'}{x_b}\right) = 0.003\left(\frac{12.19 - 3.38}{12.19}\right) = 0.0022$$

$$\epsilon_y = f_y/E_s = 60/29{,}000 = 0.0021$$

$\epsilon_s' > \epsilon_y$ COMPRESSION STEEL YIELDS

$$C_s = A_s'(f_y - 0.85 f'_c) = 0.44(60 - 0.85(4)) = 24.9^k$$

CLIENT	JOB NUMBER
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$P_b = C_c + C_s - T = 422.7^k + 24.9^k - 52.8^k = 394.8^k$

$M_b = P_b e_b$

$P_b e_b = C_c(d - a/2 - d'') + C_s(d - d' - d'') + Td''$

$a = \beta_1 x_b = 0.85(12.14'') = 10.36''$

$P_b e_b = [422.7(20.6 - 10.36/2 - 8.41) + 24.9(20.6 - 3.38 - 8.41) + 52.8(8.41)]/$

$P_b e_b = 302.2$ ft·k

$P_b = 394.8$ k

$e_b = 302.2$ ft·k $(12\text{in}/\text{ft})/394.8^k = 9.19''$

$e > e_b$ TENSION CONTROLS

CALCULATE P_n (EQ. 13.14.6, P 431, WANG & SALMON)

$m = 17.45$

$\rho = A_s/bd = 0.88/[(12)(20.6)] = 0.0036$

$\rho' = A_s'/bd = 0.44/[12(20.6)] = 0.0018$

$e' = e + d'' = 35.8 + 8.41 = 44.21$

SOLVING THE EQ. ON p. 31 YIELDS

$P_n = 40.54^k$ (FROM EQ. PROGRAMMED IN CALCULATOR)

SEE NOTE @ BOTTOM OF P. 31

$0.10 f'_c A_g = 0.10(4.0)(12)(24) = 115$

$\phi = 0.70 + [(115 - 18.6)/115](0.20) = 0.87$

$\phi P_n = 0.87(40.54^k) = 35.27^k$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
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$\phi P_n > P_u \quad 35.27^k > 18.6^k$ (OK)

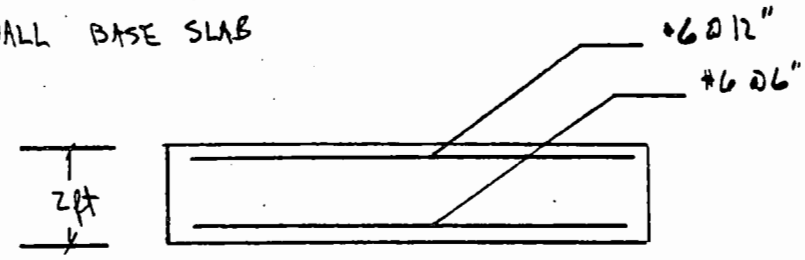
BY INSPECTION NEGLECT SLENDERNESS EFFECTS

$P_{nc} = M_n$

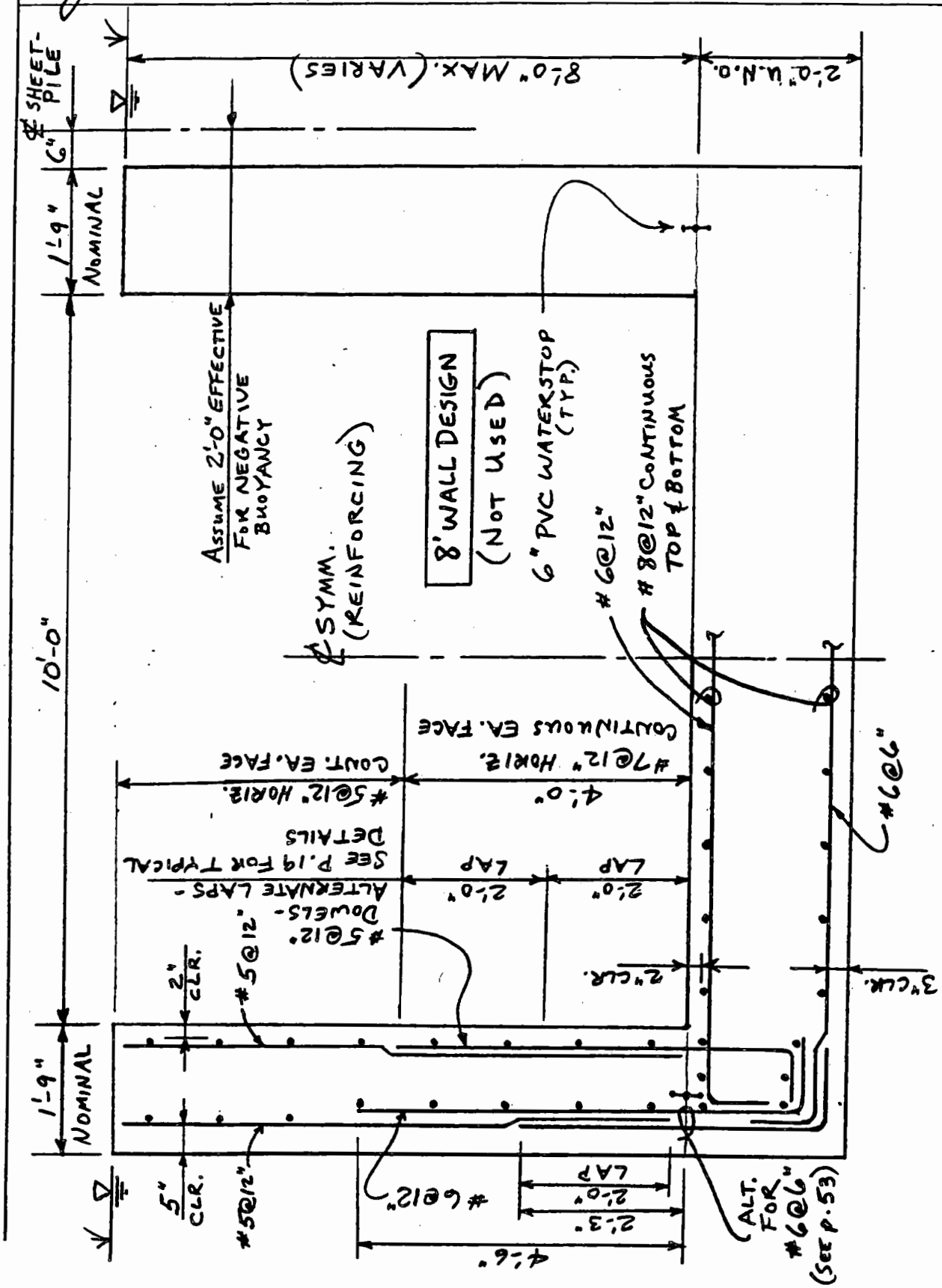
$M_n = 40.54^k/35.8'')(1^{ft}/12\,in) = 120.9\ ft\cdot k$

$\phi M_n = 0.87(120.9) = 105.2\ ft\cdot k \qquad \phi M_n > M_u \quad 105.2\ ft\cdot k > 55.5\ ft\cdot k$ (OK)

8 ft WALL BASE SLAB

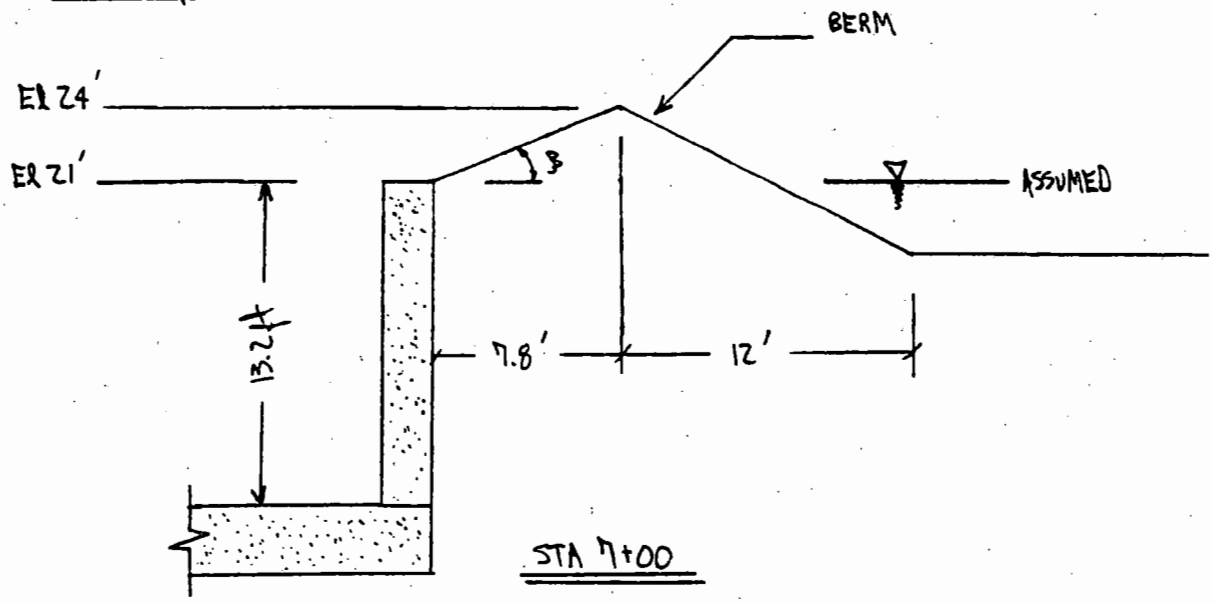


CLIENT	JOB NUMBER
Sun Oil	RC-0086
SUBJECT: Concrete Trench Design	
BASED ON	DRAWING NUMBER
BY: J. Schmohl / CHECKED BY: R DUNCAN	APPROVED BY / DATE: 12/2/92



CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	
BY / CHECKED BY	APPROVED BY / DATE
M DYE / J. Schmohl	10/19/92

13.2 ft WALL DESIGN



AS STATED ON P. 101, 103 & 119 THE 13.2 ft HIGH WALL WILL RANGE FROM STA 5+00 TO STA 7+00 ON THE RIGHT SIDE OF THE TRENCH. STA 7+00 HAS THE STEEPEST SLOPE TO THE TOP OF THE BERM AND THE HIGHEST WALL HEIGHT, THEREFORE THE ANALYSIS AND DESIGN OF THE WALL FROM STA 5+00 TO STA 7+00 WILL BE BASED ON STA 7+00.

THE HEIGHT OF THE SOIL FROM THE TOP OF THE WALL TO THE TOP OF THE BERM AND THE DISTANCE FROM THE OUTSIDE OF THE WALL TO THE TOP OF THE BERM AND BEYOND WAS SCALED FROM CIVIL'S SECTIONS OF THE CONVEYANCE TRENCH.

EVEN THOUGH THE BERM REACHES ITS MAX. HEIGHT 7.8' FROM THE EXTERIOR FACE OF THE TRENCH WALL, BASE THE LATERAL EARTH PRESSURES ON SLOPING BACKFILL. ALSO, ASSUME THE WATER LEVEL IS AT EL 21'.

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	

BY	CHECKED BY	APPROVED BY	DATE
M DYE	J. Schmehl		10/19/92

FOR SLOPING BACKFILL,

$$K_a = \frac{\sin^2(\alpha+\phi)}{\sin^2\alpha\,\sin(\alpha-\delta)\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi-\beta)}{\sin(\alpha-\delta)\sin(\alpha+\beta)}}\right]^2} \qquad \text{(EQ 11-3)}$$

$$K_p = \frac{\sin^2(\alpha-\phi)}{\sin^2\alpha\,\sin(\alpha+\delta)\left[1-\sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi+\beta)}{\sin(\alpha+\delta)\sin(\alpha+\beta)}}\right]^2} \qquad \text{(EQ 11-6)}$$

REFERENCE: "FOUNDATION ANALYSIS AND DESIGN, 2nd ed", JOSEPH E. BOWLES
PP 328 & 329

NEGLECT WALL FRICTION ∴ $\delta = 0$
$\phi = 5°$ (TABLE 6.0 SOILS REPORT, "LOOSE" FILL)
$\alpha = 90°$ (SMOOTH VERTICAL WALL)
$\beta = \tan^{-1}(3/7.8) = 21° > 4 \times \phi$ (THIS INDICATES AN UNSTABLE CONI WAS ASSUMED - SEE NOTE ON NEXT PAGE)

WHEN CALCULATING K_a AN IMAGINARY NUMBER IS OBTAINED WHEN TRYING TO TAKE THE SQUARE ROOT. THEREFORE, SAY THAT TERM IS 0.
THUS,

$K_a = 0.99$ SAY $K_a = 1.0$

$K_p = 1.56$

THERE ARE NO EQUATIONS TO CALCULATE K_0 FOR SLOPING BACKFILL. THEREFORE ASSUME LINEAR RELATIONSHIP BETWEEN SLOPING BACKFILL AND HORIZONTAL BACKFILL AND INTERPOLATE.

CLIENT	JOB NUMBER
SUN OIL	RC-0086
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HORIZONTAL BACKFILL

$k_a = 0.83$
$k_o = 0.91$
$k_p = 1.19$

"LOOSE" FILL
TABLE 6.0 SOILS REPORT

SLOPING BACKFILL

$k_a = 1.0$
$k_o = ?$
$k_p = 1.56$

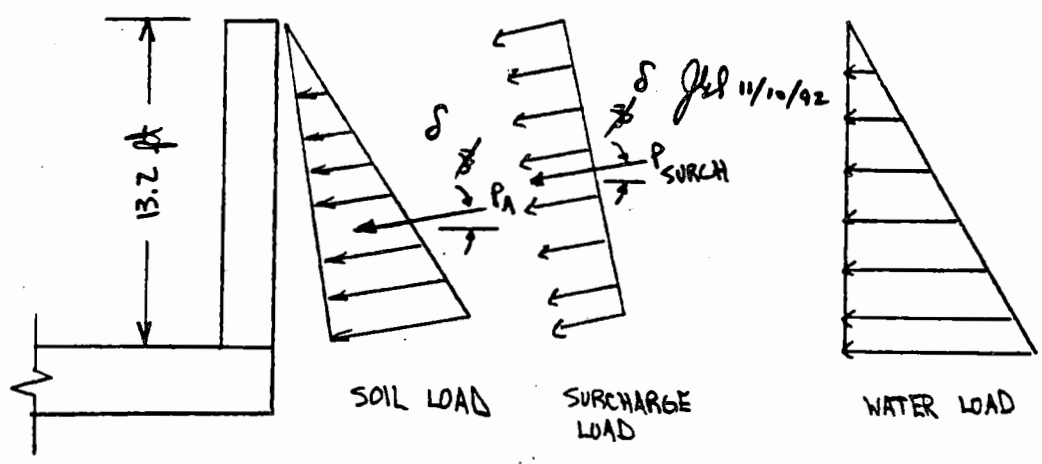
$$\frac{k_a - k_o}{k_a - k_p} = \frac{k_a - k_o}{k_a - k_p} \; ; \quad \frac{0.83 - 0.91}{0.83 - 1.19} = \frac{1.0 - k_o}{1.0 - 1.56}$$

$$\frac{-0.08}{-0.36} = \frac{1.0 - k_o}{-0.56}$$

$$0.0448 + 0.36 = 0.36(k_o)$$

$k_o = 1.12$ FOR SLOPING BACKFILL

EXTERIOR WALL LOADS



JHS 11/10/92

NOTE: COEFFICIENTS K_a & K_o CALCULATED ABOVE APPEAR TO BE CONSERVATIVE SINCE $\sin^2(\alpha \pm \phi)$ IS LARGER FOR $\phi = 5°$ THAN FOR $\phi = 21°$ (STABLE CONDITION) SEE ATTACHED SHEET FOR $\beta/\phi = 1$ AND $\delta = 0$. JHS 11/10/92

REDUCTION FACTOR (R) OF K_p FOR VARIOUS RATIOS OF $-\delta/\phi$

ϕ \ δ/ϕ	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	-0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.276	.221	.174

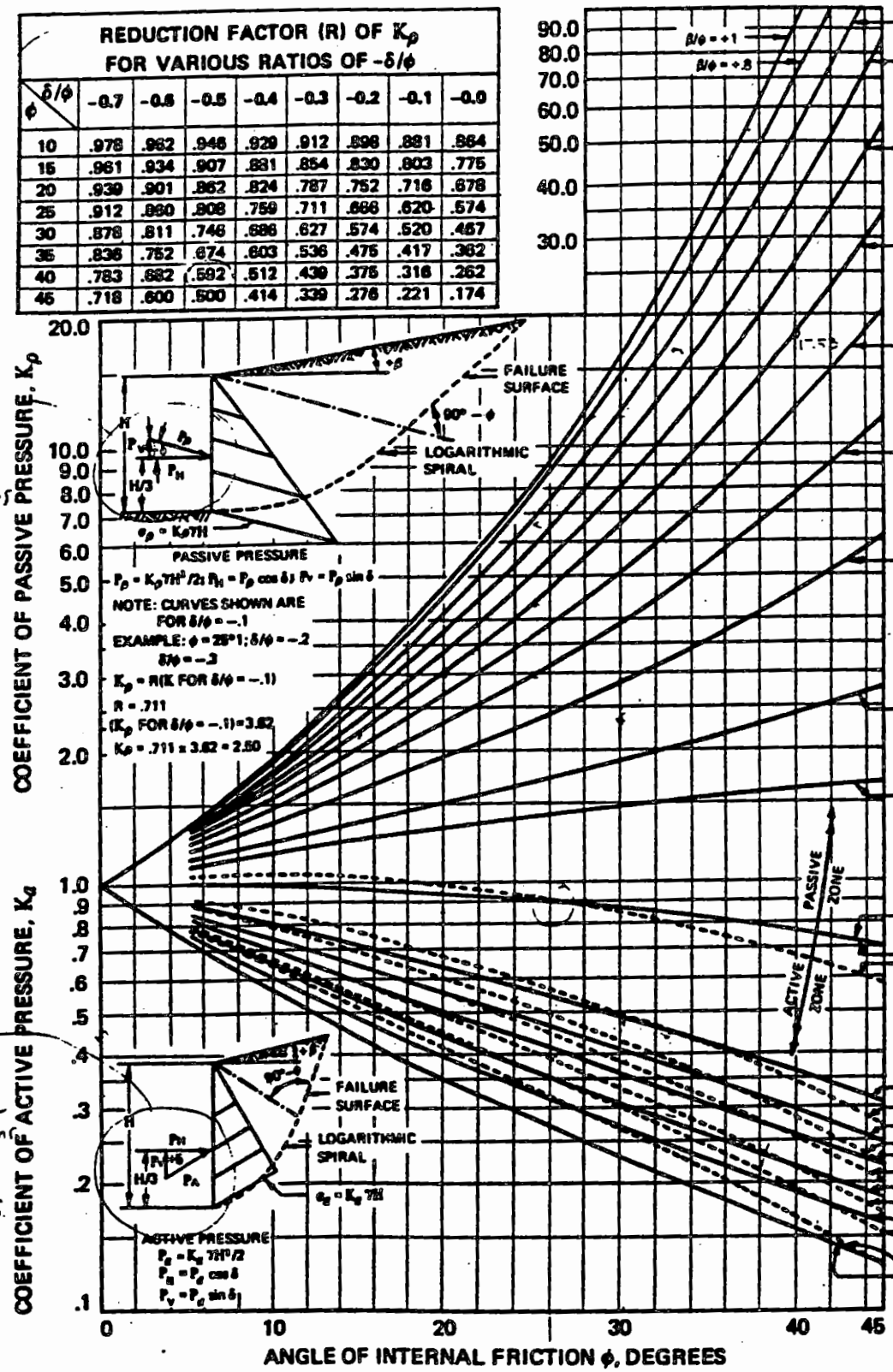


Fig. 5(a) — Active and passive coefficients with wall friction (sloping backfill) (after Caquot and Kerisel[21])

CLIENT Sun Oil		JOB NUMBER RC-0086	
SUBJECT Concrete Trench Design			
BASED ON		DRAWING NUMBER	
BY J. Schmohl	CHECKED BY R DUNCAN	APPROVED BY	DATE 11/9/92

Effect of Soil Berm on Wall Forces & Moments:

The assumption that the soil at the top of the wal is a sloping backfill is conservative. However, as shown on the next page, this soil is considered to be applied at its buoyed weight of 43 pcf. This is non-conservative, as the berm is probably composed of a soil closer to the Stratum "F" dense fill, with a saturated weight of 125 pcf.

In order to compensate for the heavier (assumed saturated fill in the berm above the assumed groundwater level of El. 21.0', the berm soil above the water line will be added as a soil surcharge on the wall.

Assume the soil surcharge with an average depth of

$$(El.24 - El.21)/2 = 3'/2 = 1.5'$$

This soil surcharge will be applied using the at-rest pressure coefficients.

For Information Only:

If the entire berm above El. 21 were considered a surcharge, and level backfill coefficients were used, resultants would be

Soil Surcharge	125 pcf $(3'/2)(13.2)(1ft)(0.91)$	= 2,252 lb	× 6.6'	= 14,865 ft.
Live Load Surcharge	400 psf $(13.2')(1ft)(0.83)$	= 4,382	× 6.6'	= 28,924
Soil (Level)	$1/2(43 pcf)(13.2)^2(1ft)(0.91)$	= 3,409	× 4.4'	= 15,000
Water	$1/2(62.4)(13.2)^2(1ft)(1.00)$	= 5,436	× 4.4'	23,920
		15,479 lb		82,709 ft.

Since there is a possibility that considering the entire berm as a surcharge may be non-conservative (the berm may act more like a strip or line load, applying more pressure near the top of the wall) the sloping backfill approach will be used with the addition of a soil surcharge 1.5' deep.

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SUN OIL	RC-0086

SUBJECT: CONCRETE TRENCH DESIGN

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ACI 350-89 ALTERNATE DESIGN METHOD	

BY	CHECKED BY	APPROVED BY	DATE
M DYE / J. Schmohl	TR DUNCAN		10/20/97

RESULTANTS

SOIL SURCHARGE - $(\gamma_{max} - \gamma_B)(3'/2)(H)(1ft)(K_o)(\cos\delta)$ @ H/2 ABOVE BASE

SOIL - $1/2(\gamma_B)(H)^2(1ft)(k_o)(\cos\delta)$ @ H/3 ABOVE BASE

LL SURCHARGE - SURCHARGE $(H)(1ft)(k_a)(\cos\delta)$ @ H/2 " "

WATER - $1/2(\gamma_w)(H)^2(1ft)$ @ H/3 " "

SOIL - $1/2(43\ pcf)(13.2\ ft)^2(1ft)(1.12)(\cos 0°) = 4,196^{lb}$ @ 4.4 ft

LL SURCHARGE - $400\ psf(13.2\ ft)(1ft)(1.0)(\cos 0°) = 5,280^{lb}$ @ 6.6 ft

WATER - $1/2(62.4\ pcf)(13.2\ ft)^2(1ft) = 5,436^{lb}$ @ 4.4'

SOIL SURCHARGE $(125-43\ pcf)(3'/2)(13.2')(1')(1.12)(\cos 0°) = 1,819^{lb}$ @ 6.6'

V = SHEAR @ BASE OF WALL = $4.20^k + 5.28^k + 5.44^k + 1.82^k = 16.74^k$

M = MOMENT @ BASE OF WALL = $4.20^k(4.4\ ft) + 5.28^k(6.6\ ft) + 5.44^k(4.4\ ft) + 1.82^k(6.6') = 89.28'^k$

- GENERAL EQUATION FOR MOMENT (ft·k)

$$M = \left[1/2(\gamma_B)(H)^2(k_o)(\cos\delta)(H/3) + \text{SURCHARGE}(H)(k_a)(\cos\delta)(H/2) + 1/2(\gamma_w)(H^2)(H/3) + \text{SOIL SCHG.}(H)(K_o)(\cos\delta)(H/2)\right]/1000$$

$$M = 0.00803H^3 + 0.200H^2 + 0.0104H^3 + 0.0689H^2$$

* $$M = 0.01843H^3 + 0.269H^2$$

CHECK W/ H = 13.2 ft M = 89.26 ft·k (OK)

- GENERAL EQUATION FOR SHEAR (KIPS)

$$V = \left[0.5(\gamma_B)(H^2)(k_o)(\cos\delta) + \text{SURCHARGE}(H)(k_a)(\cos\delta) + 1/2(\gamma_w)(H^2) + \text{SOIL SCHG.}(H)(K_o)(\cos\delta)\right]/1000$$

* $$V = 0.0553H^2 + 0.5377H$$

CHECK W/ H = 13.2 ft V = 16.73^k (OK)

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- CALCULATE WALL THICKNESS BASED UPON SHEAR

A.7.1 SHEAR STRESS $v = \frac{V}{b_w d}$

A.7.4 SHEAR STRESS MUST NOT EXCEED v_c AND $v_c = 1.1\sqrt{f'_c}$

A.7.5.5 SHEAR REINF. NOT REQ'D SINCE "BEAM" DEPTH NOT GREATER THAN ½ THE WIDTH OF THE WEB (½ LENGTH OF WALL)

$\therefore v_c = 1.1\sqrt{4{,}000\ psi} = 69.6\ psi$

$v \le v_c$

$\frac{V}{b_w d} \le 69.6\ psi$

$\frac{16.73^k \left(1000\ lb/1k\right)}{12''\ (d)} \le 69.6\ psi$

$d \ge 20.0''$

ASSUME #10 BAR (NOTE: Need 2½" Min. Cover for ACI 318 12.2.3.1(d) for dowel development length

$t \ge 20'' + \frac{1}{2}(1\frac{1}{4}'') + \underline{\underline{3''}}\ (\text{cover}) + 3''\ (\text{SHEETPILE TOLERANCE}) = 26.6''$

TRY USING A 2'-3" WALL

FOR CALCULATIONS INVOLVING BUOYANCY USE WALL THICKNESS = 2'-0
(2'-3" WALL - 3" SHEETPILE TOLERANCE)

FOR CALCULATIONS INVOLVING MOMENT USE
$d = 2'\text{-}3''\ \text{WALL} - 3''\ (\text{SHEETPILE}) - 3''\ (\text{cover}) - \frac{1}{2}\left(\frac{10}{8}\right) = 20.4''$

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- BASED ON FLEXURE CHECK THE "d" PROVIDED BASED ON SHEAR WITH THE "d" REQ'D FOR FLEXURE

$$\text{REQ'D "d"} = \sqrt{\frac{2M}{f_c b k j}} \qquad (P.6)$$

$$\left.\begin{aligned} k &= 3/8 \\ j &= 7/8 \\ f_c &= 1.80 \text{ ksi} \end{aligned}\right\} (P.6)$$

$$\text{REQ'D "d"} = \sqrt{\frac{2(89.26\ ft\cdot k)(12''/ft)}{1.80 \text{ ksi}\,(12'')(3/8)(7/8)}} = 17.4''$$

REQ'D "d" < "d" PROVIDED $\qquad 17.4'' < 20.4''$ (OK)

$$A_{s\,REQ'D} = \frac{M}{f_s j d} = \frac{89.26\ ft\cdot k\,(12\text{in}/ft)}{24 \text{ ksi}\,(7/8)(20.4'')} = 2.50 \text{ in}^2$$

BASED ON ACI A.3.2(b)

CAN USE #10 @ 6" $\qquad A_s = 2.54 \text{ in}^2$

CRACKING

#10 @ 6" $\quad f_{s\,ALLOW} = 25.8$ ksi (ACI 350 FIG 2.6.7(c))

$f_{s\,ACTUAL} = 89.26(12)/[2.54(7/8)(20.4)] = 23.5$ ksi $\qquad$ (OK)

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13.2 ft WALL

$M_{200/f_y} = 24^{ksi}(0.81\ in^2)(7/8)(20.4")(1\ ft/12\ in.) = 28.92'^k$

DISTANCE DOWN WALL WHERE M_{200/f_y} OCCURS

$28.92\ ft\cdot k = 0.01843x^3 + 0.269x^2$ $\quad x = 8.28\ ft$

$M_{ACT} = 89.26\ ft\cdot k$

FIND THE DISTANCE DOWN THE WALL WHERE THE WALL CAN BE DESIGNED FOR $4/3\ M_{ACT}$

$1.33(0.01843x^3 + 0.269x^2) = 28.92'^k$ $\quad x = 7.33\ ft$

USE #10 DOWEL @ 6" SO THAT #6 @ 12 CAN BE USED @ TOP OF WALL

I WANT TO SPLICE THE #10 @ 6" W/ #8 @ 12" AND #6 @ 12"

MUST ALTERNATE SPLICES

SPLICE #8 $\quad 1.3(28.5") = 37.1"$ SAY 3'-2"
SPLICE #6 $\quad 1.3(21.3") = 27.7"$ SAY 2'-4" $\quad \lambda = 20.4"$

DISTANCE DOWN WALL WHERE #6 @ 12" CAN BE USED $\quad f_s = 21.6$ ksi (ACI 350
$A_s = 0.44\ in^2$

$$21.6 = \frac{1.33(0.01843x^3 + 0.269x^2)(12)}{0.44(7/8)(20.4")} \qquad x = 5.37\ ft$$

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DISTANCE DOWN WALL WHERE #8 @ 12" AND #10 @ 12" CAN BE USED

$f_s = 25.8$ ksi (ACI 350 FIG 2.6.7(c)) (Bars @ 6" o.c., #10 Max. Size)

$A_s = 0.79 + 1.27 = 2.06 \text{ in}^2$

$$25.8 = \frac{1.33(0.01843x^3 + 0.269x^2)(12)}{2.06(7/8)(20.4)}$$

$x = 11.18$ ft (See Shear Chec
Below ⇒ $x = 10.$

DISTANCE DOWN WALL WHERE #8 @ 12" AND #6 @ 12" CAN BE USED

$f_s = 27.3$ ksi (ACI 350 FIG 2.6.7(b)) (Bars @ 6" o.c., #8 Max. Size)

$A_s = 0.79 + 0.44 = 1.23 \text{ in}^2$

$$27.3 = \frac{1.33(0.01843x^3 + 0.269x^2)(12)}{1.23(7/8)(20.4)}$$

$x = 9.24$ ft

ACI 318 12.10.5 CHECK

V_s @ 11.18 ft $= 0.0553(11.18 \text{ ft})^2 + 0.5377(11.18)$

$V_s = 12.92^k$

$v = V_s/bd = 12.92^k/(12)(20.4) = 52.8$ psi No Good!

$2/3\ v_{c\ \text{Allowable}} = 46.4$ psi

Reduce to $x = 10.25'$

$V_s = 11.32^k$

$v = 46.2$ psi < 46.4 psi Allowable (OK)

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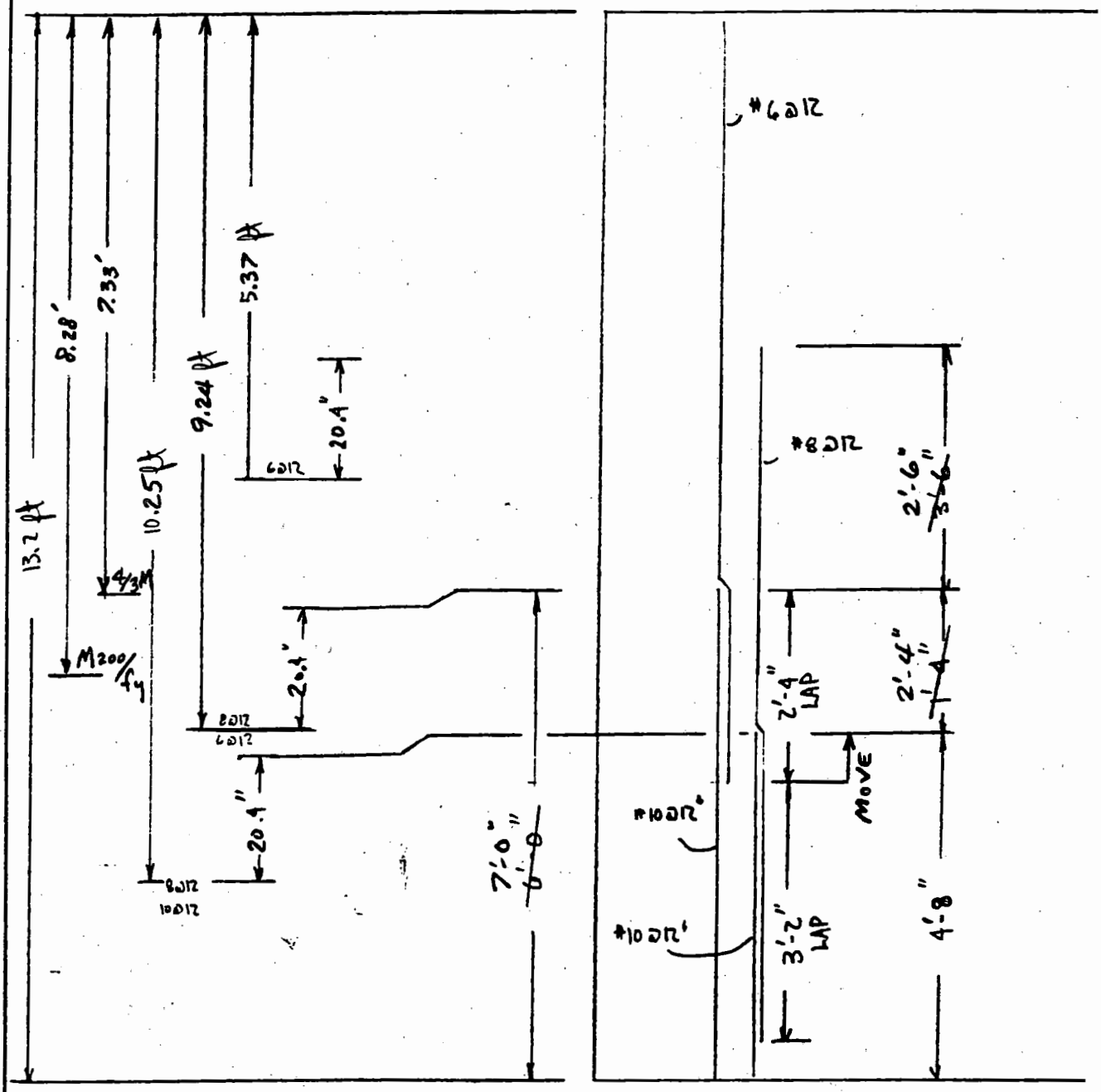

INSIDE FACE OF WALL: USE #6@12" & STAGGER LAPS (2'-4" EA
SIMILAR TO #5@12" FOR 11.2' WALL

To simplify reinf. details, move #6 splice up 1'-0" so that #8 splice starts @ Top of #10 dowel. (Net change in rebar wt. = + 0.13 lb/ft of

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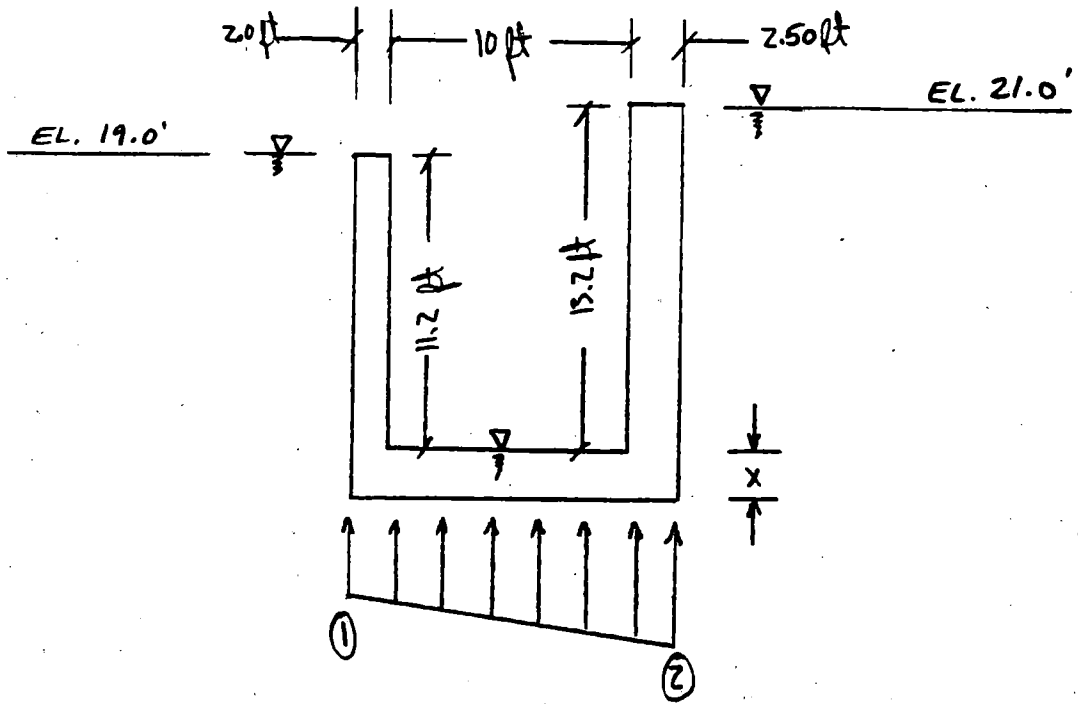
DESIGN BOTTOM SLAB

THE 13.2 ft WALL RANGES FROM STA 5+00 TO STA 7+00 ON THE RIGHT SIDE OF THE TRENCH & FROM 8+00± TO 10+50 ON BOTH SIDES OF THE TRENCH.

THE LEFT SIDE OF THE TRENCH HAS TWO DIFFERENT WALL HEIGHTS FROM STA 5+00 TO STA 7+00 (10 ft, & 11.2 ft). THE WALL THICKNESS IS THE SAME FOR EACH, SO THE GREATEST UPLIFT FORCE WILL BE FOR THE 11.2 ft WALL. THEREFORE, CALCULATE THE BUOYANCY BASED ON THE FOLLOWING.



PRESSURE @ 1 = 62.4 pcf (11.2 ft + x) = 699 + 62.4(x)

PRESSURE @ 2 = 62.4 pcf (13.2 ft + x) = 824 + 62.4(x)

2 - 1 = 125

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$$\downarrow \Sigma F = \uparrow \Sigma F$$

$$\downarrow \Sigma F = 2\,ft(11.2\,ft)(1\,ft)(.15\,kcf) + 2.50\,ft(13.2\,ft)(1\,ft)(.15\,kcf) + 14.50\,ft(1\,ft)(x)(.15\,k$$

$$= 8.31^{k} + 2.175x$$

$$\uparrow \Sigma F = \left(\left[699 + 62.4(x)\right]/1000\right)(1\,ft)(14.50\,ft) + \tfrac{1}{2}(125\,psf)(14.50\,ft)(1\,ft)/1000$$

$$= 11.04^{k} + 0.905x$$

$$8.31 + 2.175x = 11.04 + 0.905x$$

$$1.27x = 2.73 \qquad x = 2.15\,ft$$

USE 2'-3" SLAB

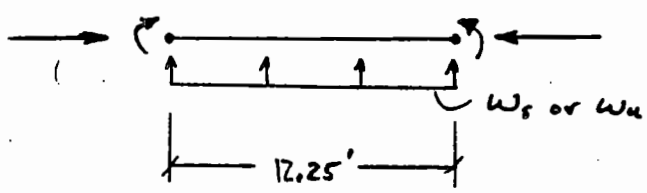
CALCULATE THE MOMENT ON THE BASE SLAB

NET UPLIFT LOAD ACTING ON SLAB = WEIGHT WALLS/TRENCH WIDTH

$= 8.31^{k}/14.50' = 0.57\,k/ft$

or Avg. Hydrostatic Pressure - DL slab $= \left[22.25'(62.4) - 2.25(150)\right]/1000 = 1.05\,k/ft$

Say $w_s = 0.57\,k/ft$ $\qquad w_u = 1.3(1.7)(0.57) = 1.26\,k/ft$



$$M_{s_{POS}} = w_s l^2/8 = 0.57\,k/ft(12.25\,ft)^2/8 = 10.69\,ft\cdot k$$

$$M_{u_{POS}} = w_u l^2/8 = 1.26\,k/ft(12.25\,ft)^2/8 = 23.63\,ft\cdot k$$

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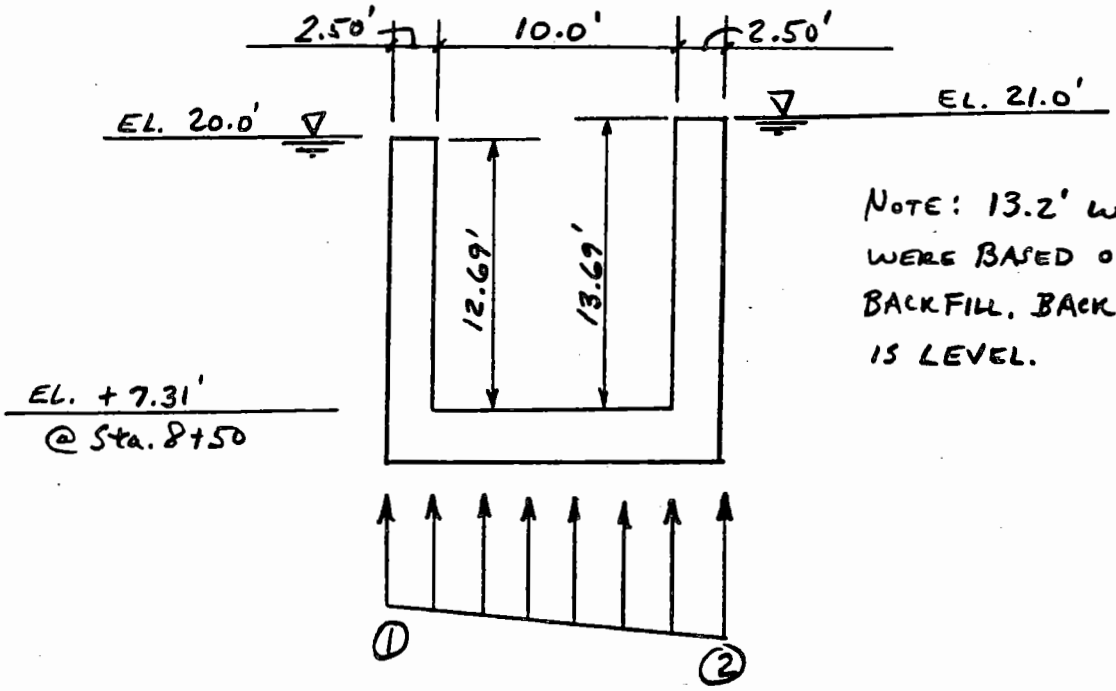
Check the case for 13.2' wall Designs both Sides of the Trench (Sta. 8+00± TO Sta. 10+50). Use Sta 8+50 for Design with 13.69' high wall (level backfill) on west side of trench and 12.69' high wall (level backfill) on east side of the trench.



NOTE: 13.2' WALL DESIGN WERE BASED ON SLOPING BACKFILL. BACKFILL HERE IS LEVEL.

Pressure @ ① = 62.4 pcf (12.69' + x) = 792 + 62.4x
" ② = 62.4 pcf (13.69' + x) = 854 + 62.4x
① − ② = 62.4 psf

$\Sigma F \downarrow = 2.5'(12.69')(1ft)(0.15\ kcf) + 2.5'(13.69')(1')(0.15\ kcf) + 15.0'(1')(x)(0.15\ k$
$= 9.89^k + 2.25x$

$\Sigma F \uparrow = (792 + 62.4x)(1')(15.0')/1000 + \frac{1}{2}(62.4\ pcf)(15.0')(1')/1000$
$= 12.35^k + 0.94x$

Combine to get

$1.31x = 2.46^k$

$x = 1.88'$ Use 2'-3" slab to match wall moment

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AXIAL LOAD ON SLAB (11.2 ft WALL + 2.25 ft SLAB = 13.45 ft DOWN FROM TOP OF WALL)

$V_u = 1.3(1.7)[(332)(x) + 39(x)(x)(1/2) + 62.4(x)(x)(1/2)]/1000$ (P. 22)

$P_u = V_u$ @ 13.45 ft DOWN FROM TOP OF WALL = 30.14^k ; V_s = 13.64^k

AXIAL LOAD ON SLAB (13.2 ft WALL + 2.25 ft SLAB = 15.45 ft DOWN FROM TOP OF WALL)

$V_u = 1.3(1.7)[0.0553H^2 + 0.5377H]$ (P. 67)

$P_u = V_u$ @ 15.45 ft DOWN FROM TOP OF WALL = 47.53^k ; V_s = 21.51^k

MOMENT ON SLAB FROM 11.2 ft WALL (See Equation on p. 11)
$M_u = 1.3(1.7)(M_s @ 12.33') = 125.8'^k$ $M_s = 56.92'^k$
MOMENT ON SLAB FROM 13.2 ft WALL (See Equation on p. 67)
$M_u = 1.3(1.7)(M_s @ 14.33') = 241.9'^k$ $M_s = 109.5'^k$
DESIGN THE BASE SLAB ON FLEXURE USING THE MOMENT FROM THE 13.2 ft WALL

BOTTOM STEEL

$M_u = 241.9$ ft·k

ASSUME #8 BAR

$d = 2.25$ ft − 3" (cover) − 1/2(1") = 23.5"

$R_n = M_u/\phi b d^2 = \dfrac{241.9 \text{ ft}\cdot k\,(12{,}000)}{0.9(12)(23.5)^2} = 487$ psi

$\rho_{REQ'D} = 0.0088$ ← CONTROLS

$\rho_{min} = 200/F_y = 0.0033$

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$A_{s_{REQ'D}} = \rho b d = 0.0088(12)(23.5) = 2.48 \text{ in}^2$

TRY #10 @ 6" $A_s = 2.54 \text{ in}^2$ $d = 23.4"$

CHECK CRACKING

$f_{s_{ALLOW}} = 25.8 \text{ ksi}$ (ACI 350 FIG 2.6.7(c))

$f_{s_{ACTUAL}} = \dfrac{M_s}{A_s j d} = \dfrac{109.5 \text{ ft-k } (12 \text{ in/ft})}{2.54(7/8)(23.4)} = 25.3 \text{ ksi}$

$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ 25.3 ksi < 25.8 ksi (ok) USE #10 @ 6"

TOP STEEL

~~$R_n = M_u / \phi b d^2$~~ Use #6 @ 12" (See p. 26)

$R_n = \dfrac{18.34 \text{ ft-k } (12{,}000)}{0.9(12)(26.5)^2} = 29 \text{ psi}$

$\rho = 0.0005$

$\rho_{min} = 200/F_y$ or 1.33ρ or 0.0018

$\rho_{min} = 0.0018$

$A_{s_{REQ'D}} = \rho b h = 0.0018(12)(30) = 0.65 \text{ in}^2$ EACH FACE

TRY #6 @ 12" $A_s = 0.44 \text{ in}^2$

CHECK CRACKING

$f_{s_{ALLOW}} = 21.6 \text{ ksi}$ (ACI 350 FIG 2.6.7(b))

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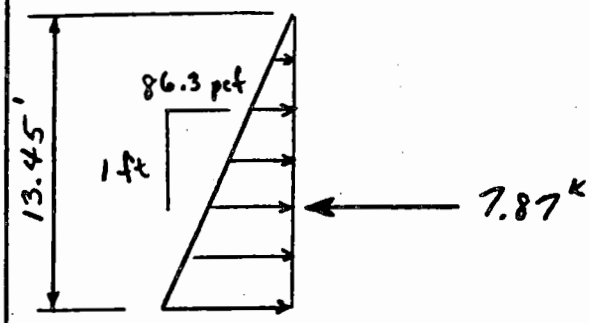
13.2 ft Wall on West Side vs. 11.2' wall on East Side

Assume the difference in slab axial loads will be taken by developing passive earth pressure against the 11.2' wall.

$$P_{s(13.2)} - P_{s(11.2)} = \overset{p.76}{21.51^k} - \overset{p.76}{13.64^k} = 7.87^k$$ Unbalanced Load per foot of wall



Passive Pressure Limit (Ref. Table 6.0-Soil Rep for type "F-Dense"-See Note Belo

$$= (K_p - K_o)\gamma_b$$
$$= (2.03 - 0.66)(63\ pcf) = 86.3\ pcf$$

$$R_{P_{max.}} = 86.3\ pcf\,(H)(H/2)(1\ ft)$$
$$= 86.3\,(13.45)\left(\frac{13.45}{2}\right) = 7{,}806\ lb$$

This is almost equal to the unbalanced force 7,870 lb. This without considering sliding friction on the base slab or the reduction of wall forces as we go from the max. height of fill (13.2' wall) @ Sta. 7+00 to lower fill heights as we go toward Sta. 5+00. Thus, the resistance offered by the 11.2' wall should be satisfactory.

See "Note" on page 93 of the 16.4' wall design for discussion regarding the use of type "F-Dense" fill.

$\therefore V_p = 6.41^k$
$V_s = 10.08^k$
15.49^k vs. 10.08^k (p.11)
No Good!

Add'l Moment at Base of 11.2' Wall due to passive pressure

$$M_p = .0863\ pcf\,(11.2')^3(1\ ft)/6 = 20.2'^k$$
$$M_s = 0.0169(11.2')^3 + 0.166(11.2')^2 = 44.6$$
$$64.8'^k > 44.6'^k \text{ for } 11.2' \text{ WALL DESIGN}$$

$\therefore$ Must Use 13.2' Wall Design on Left Side of Trench Also!

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~~$f_{s_{ACTUAL}} = \frac{M_s}{A_s j d} = \frac{10.12\ ft\cdot k\ (12in/ft)}{0.44(7/8)(26.5)} = 11.9\ ksi$~~

~~$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ 11.9 ksi < 21.6 ksi (OK)~~

USE #6 @ 12"

ANALYZE THE SLAB FOR COMBINED BENDING AND AXIAL LOAD

$M_{u_{11.2}} = 1.3(1.7)(83.9'^k) = 185.4'^k$

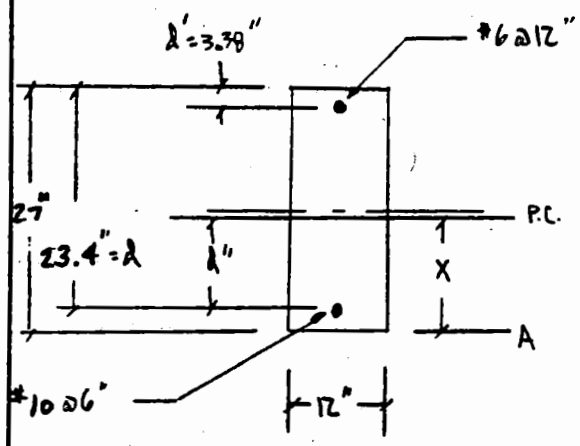
(See p. 77A w/ H = 12.33'

$P_{u_{11.2}} = 47.5^k \longrightarrow$ (———) $\longleftarrow 47.5^k = P_{u_{13.2}}$

$M_{u_{11.2}} = 185.4\ ft\cdot k$ $\qquad$ $M_{u_{13.2}} = 241.9\ ft\cdot k$

$e_{11.2} = M_{u_{11.2}}/P_{u_{11.2}} = 46.8''$ $\qquad$ $e_{13.2} = M_{u_{13.2}}/P_{u_{13.2}} = 61.1''$

THE GREATEST ECCENTRICITY (e) IS $e_{13.2}$, THEREFORE, ANALYZE THE SLAB USING THE LOADS FROM THE 13.2 ft WALL.



3" COVER TOP & BOTTOM $\quad A_s = 2.54\ in^2 \quad A'_s = 0.44\ in^2$

FIND THE PLASTIC CENTROID

$C_1 = 0.85 f'_c (A_g - A_{st})$

$C_1 = 0.85(4)\left(12(27) - (2.54 + 0.44)\right) = 109^k$

$C_3 = A'_s f_y = 0.44(60) = 26.4^k$

$C_2 = A_s f_y = 2.54(60) = 152.4^k$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
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$$\Sigma M_A = 0 \; ; \quad X = \frac{1091^k(27/2) + 26.4^k(27-3.38) + 152.4^k(27-23.4)}{1091 + 26.4 + 152.4}$$

$$X = 12.52''$$

$$d'' = X - (27-23.4) = 12.52'' - (3.6'') = 8.92''$$

DUE TO LARGE ECCENTRICITY (e) ASSUME TENSION CONTROLS

DETERMINE ALLOWABLE AXIAL LOAD @ BALANCED CONDITION

$$X_b = 87d/[87+f_y] = 87(23.4)/[87+60] = 13.85''$$

$$C_c = 0.85 f'_c a b \qquad a = \beta_1 X_b = 0.85(13.85) = 11.77''$$

$$C_c = 0.85(4)(11.77)(12) = 480.3^k$$

$$T = A_s f_y = 152.4^k$$

CHECK TO SEE IF COMPRESSION STEEL YIELDS

$$\epsilon'_s = 0.003\left(\frac{X_b - d'}{X_b}\right) = 0.003\left(\frac{13.85 - 3.38}{13.85}\right) = 0.0023$$

$$\epsilon_y = f_y/E_s = 60/29{,}000 = 0.0021$$

$\epsilon'_s > \epsilon_y$ COMPRESSION STEEL YIELDS

$$C_s = A'_s(f_y - 0.85 f'_c) = 0.44(60 - 0.85(4)) = 24.9^k$$

$$P_b = C_c + C_s - T$$

CLIENT	JOB NUMBER
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$P_b = 480.3^k + 24.9^k - 152.4^k = 352.8^k$

$P_b e_b = C_c(d - a/2 - d'') + C_s(d - d' - d'') + Td''$

$P_b e_b = 480.3(23.4 - 11.77/2 - 8.92) + 24.9(23.4 - 3.38 - 8.92) + 152.4(8.92)$

$P_b e_b = 5764\ k\cdot''$

$P_b = 352.8^k \qquad e_b = 16.34''$

$e > e_b \qquad 61.1'' > 16.34''$ (TENSION CONTROLS)

CALCULATE P_n (EQ 13.14.6, P 431, WANG & SALMON)

$m = 17.65$
$\rho = A_s/bd = 2.54/[(12)(23.4)] = 0.0090$
$\rho' = A_s'/bd = 0.44/[(12)(23.4)] = 0.0016$
$e' = e + d'' = 61.1'' + 8.92'' = 70.02''$

$P_n = 64.70^k$

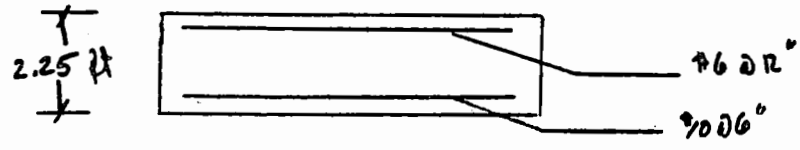
SEE NOTE BOTTOM P. 31

$0.10 f'_c A_g = 0.10(4)(12)(27) = 129.6^k$
$\phi = 0.70 + [(129.6 - 47.5)/129.6](0.20) = 0.82$

$\phi P_n \geq P_u \qquad 53.1^k \geq 47.5^k$ (OK) BY INSPECTION: NEGLECT SLENDERNES EFFECTS

$P_n e = M_n \quad \therefore \quad M_n = 64.7^k(61.1'')/12 = 329.4\ ft\cdot k$

$\phi M_n \geq M_u \qquad \phi = 0.82 \quad 270.1\ ft\cdot k \geq 241.9\ ft\cdot k$ (OK)



CLIENT Sun Oil		JOB NUMBER RC-0086	
SUBJECT Concrete Trench Design			
BASED ON		DRAWING NUMBER	
BY J. Schmohl	CHECKED BY R DUNCAN	APPROVED BY	DATE 11/30/92

Bottom Slab for 13.2' wall Design, 12' wide Ditch (Case 2) from Sta. 32+00 to Sta. 34+50.

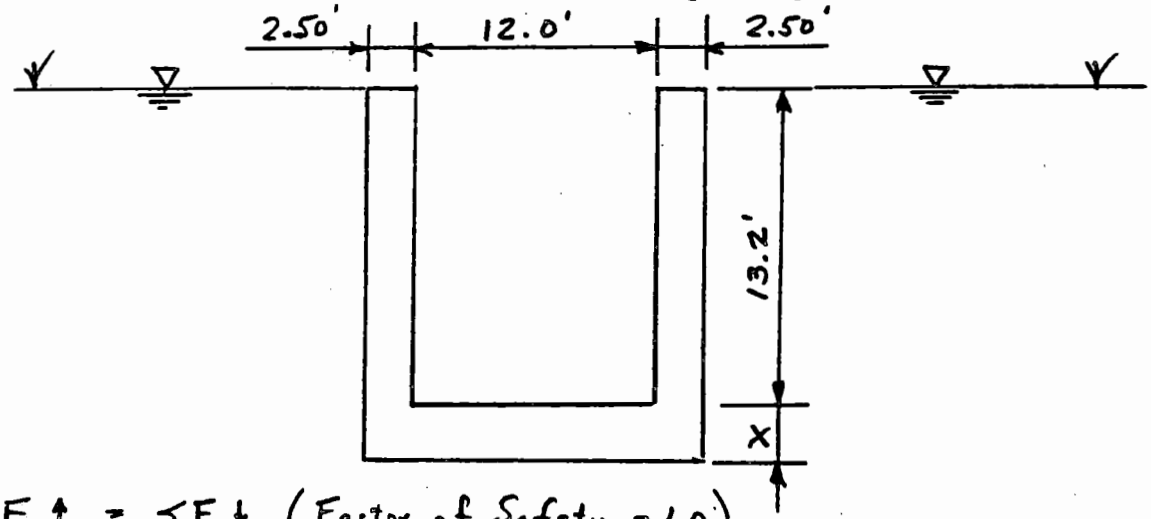
Assume bottom slab thickness will be governed by buoyancy. Worst case for design is ditch adjacent to the R.R. Box Culvert (ref. dwg. 14040A, Sta. 33+00, with top of walls @ EL. 11.0'±.

Depth of Wall @ Sta. 33+00

= Top of Wall − Top of Bottom Slab

= 11.0' − [−2.98' + (3531.5 − 3300) 0.0034]

= 11.0' − [−2.98' + 0.79'] = 11.0 − [−2.19'] = 13.19' ≈ 13.2'



$\Sigma F \uparrow = \Sigma F \downarrow$ (Factor of Safety = 1.0)

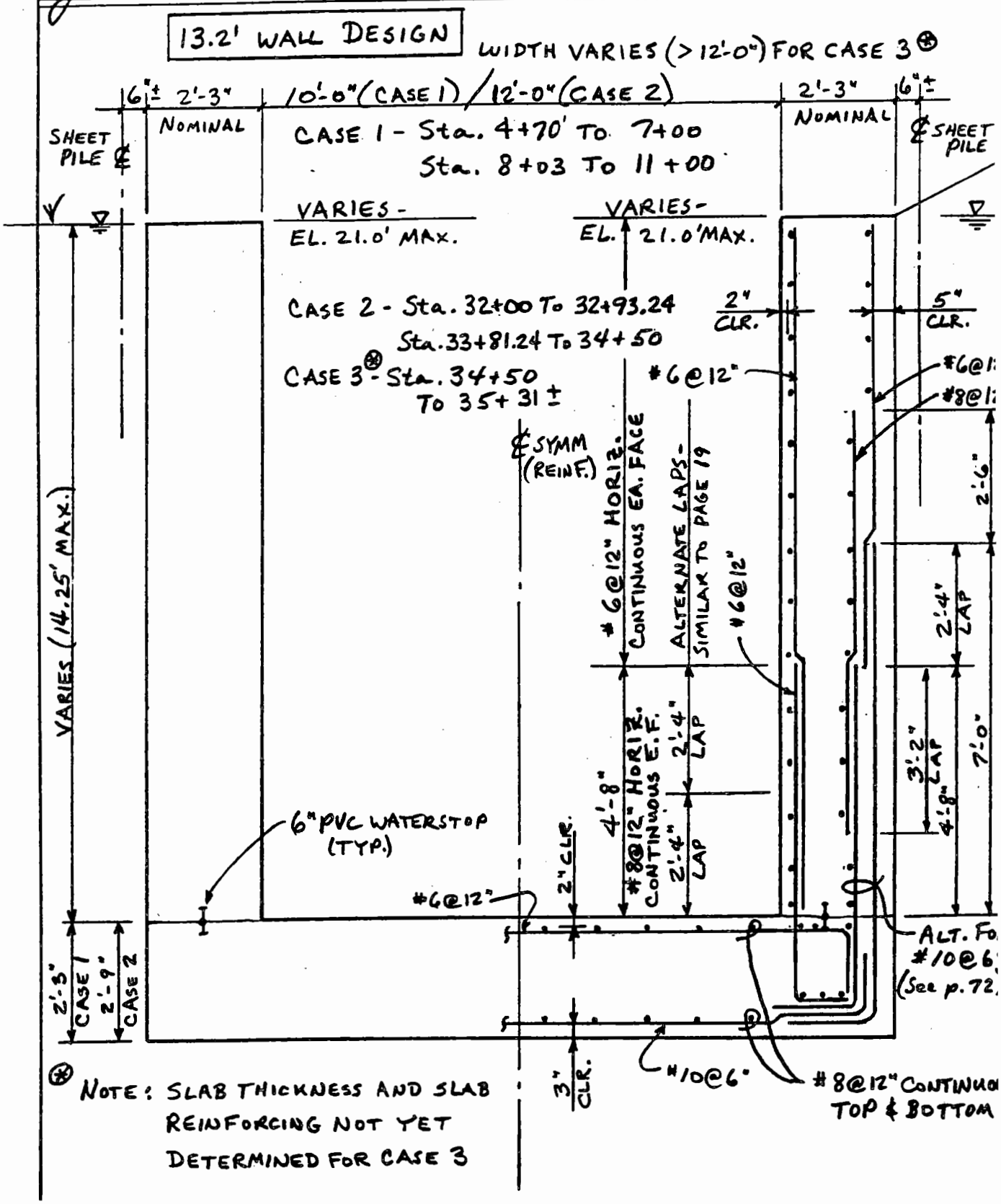
$$62.4\ pcf\,(17.0')(13.2' + x)(1ft)/1000 = 2(2.50')(13.2')(1')(0.15\ kcf) + 17.0'(x)(1')(0.15\ kcf)$$

$$14.00 + 1.061x = 9.90 + 2.550x$$

$$1.489x = 4.10 \qquad x = 2.75' \pm$$

Use 2'-9" thick slab from Sta. 32+00 to Sta. 34+50, since the above wall depth (and groundwater height) are conservative.

CLIENT Sun Oil	JOB NUMBER RC-0086		
SUBJECT Concrete Trench Design			
BASED ON	DRAWING NUMBER		
BY J. Schmohl	CHECKED BY R DUNCAN	APPROVED BY	DATE 12/2/92



⊛ NOTE: SLAB THICKNESS AND SLAB REINFORCING NOT YET DETERMINED FOR CASE 3

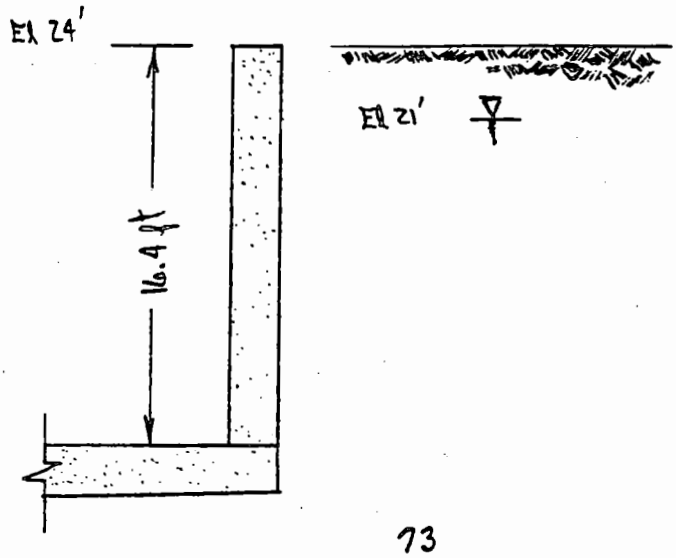
CLIENT	JOB NUMBER
SUN OIL	RC-0086

SUBJECT: CONCRETE TRENCH DESIGN

BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	

BY	CHECKED BY	APPROVED BY	DATE
M DYE	J. Schmahl		10/21/92

16.4 ft WALL DESIGN



STA 7+00 TO STA 7+~~88~~ 73 ±

AT STA. 7+00 THE WALL HEIGHT IS 13.18' AND THE WALL MUST SUPPORT A SLOPING BACKFILL

FROM STA 7+00 TO STA 7+~~88~~ 73 THE WALL HEIGHT INCREASES AND THE SLOPING BACKFILL IS LESSENED DUE TO THE WALL ELEVATION REACHING THE SAME ELEVATION AS THE TOP OF THE BERM. THEREFORE, THE STATIONS FROM 7+00 TO 7+~~88~~ 73 WILL BE DESIGNED BASED ON "LOOSE" FILL SOIL PROPERTIES AND HORIZONTAL BACKF

ALSO, THE GROUNDWATER TABLE IS ASSUMED TO BE @ EL 21' WHICH IS APPROXIMATELY 3 ft OF STANDING WATER IN THE BERM AREA.

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
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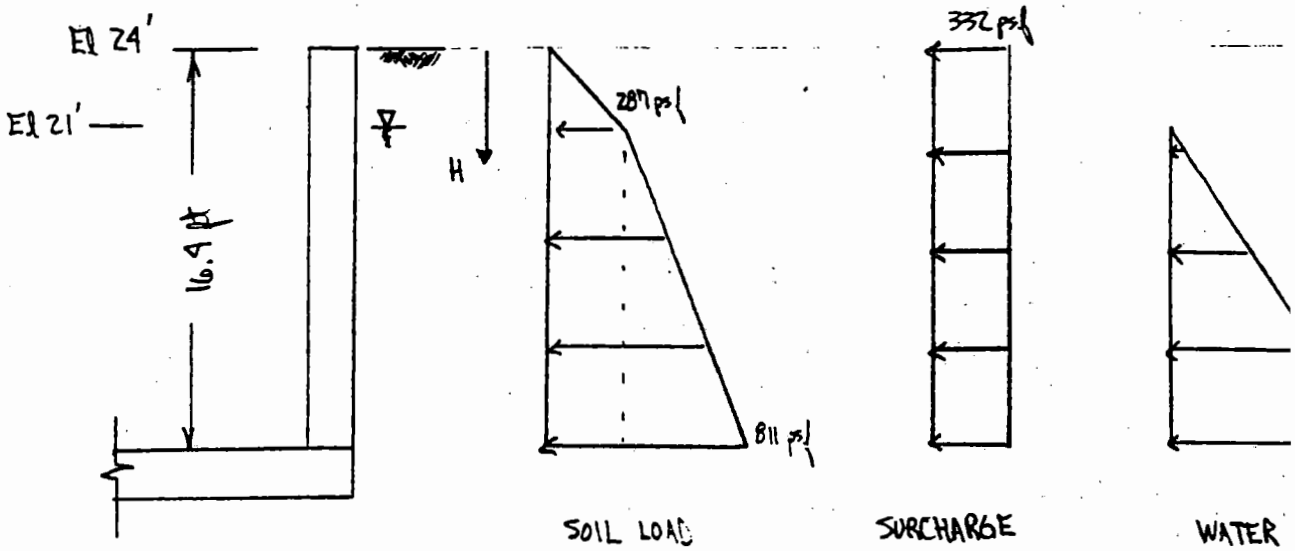
EXTERIOR WALL LOADS



$\gamma = 105$ pcf
$\gamma_b = 43$ pcf
$K_0 = 0.91$
$K_a = 0.83$

$105\text{ pcf}(0.91)(3\text{ ft})$
$43\text{ pcf}(0.91)(13.9\text{ ft})$

$400\text{ psf}(0.83)$

$62.9\text{ pcf}($

- GENERAL EQUATION FOR MOMENT ASSUMING THE HEIGHT DOWN FROM THE TOP OF THE WALL IS MORE THAN 3 ft.

$$M = \tfrac{1}{2}(287\text{ psf})(3\text{ ft})(1\text{ ft})(H-3+1) + 287\text{ psf}(1\text{ ft})(H-3)\left(\frac{H-3}{2}\right) + \tfrac{1}{2}(43\text{ pcf})(H-3)(H-3$$

$$+ 332\text{ psf}(H)(H/2) + \tfrac{1}{2}(62.9\text{ pcf})(H-3)(H-3)\left(\frac{H-3}{3}\right)$$

$$M = 0.431(H-2) + 0.287(H-3)\left(\frac{H-3}{2}\right) + 0.0215(H-3)^2\left(\frac{H-3}{3}\right) + 0.166H^2 + 0.0312$$

$$M_s = 0.431(H-2) + 0.287(H-3)\left(\frac{H-3}{2}\right) + 0.0527(H-3)^2\left(\frac{H-3}{3}\right) + 0.166H^2$$

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / CHECKED BY: J. Schmohl	APPROVED BY / DATE: 10/22/92

- GENERAL EQUATION FOR SHEAR ASSUMING THE HEIGHT DOWN FROM TH TOP OF THE WALL IS MORE THAN 3 ft

$$V = \tfrac{1}{2}(287)(3)(1) + 287(1)(H-3) + \tfrac{1}{2}(43)(H-3)^2 + 332(H) + \tfrac{1}{2}(62.4)(H-3)^2$$

$$V = 0.4305 + 0.287(H) - 0.861 + 0.0215(H-3)^2 + 0.332(H) + 0.0312(H-3)^2$$

$$V_s = 0.0527(H-3)^2 + 0.619(H) - 0.4305$$

USING EQUATIONS FIND MOMENT @ 16.4 ft DOWN FROM TOP OF WALL

$M_s = 118.9$ ft·k *

$V_s = 19.18^k$ *

CK BY HAND

$$M = \left[\tfrac{1}{2}(287)(3)(13.4 + \tfrac{1}{3}(3)) + 287(13.4)(13.4/2) + \tfrac{1}{2}(576)(13.4)(13.4/3) + 332(16.4)(16.4/2) + \tfrac{1}{2}(836)(13.4)(13.4/3)\right]/1000$$

$M = 118.9$ ft·k (EQ. OK)

$$V = \left[\tfrac{1}{2}(287)(3) + 13.4(287) + \tfrac{1}{2}(576)(13.4) + 332(16.4) + \tfrac{1}{2}(836)(13.4)\right]/1000$$

$V = 19.18^k$ (EQ. OK)

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
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- CALCULATE WALL THICKNESS BASED UPON SHEAR

$v_c = 69.6$ psi (P.3)

$v = \frac{V}{b_w d}$ (A.7.1) $\quad v \le v_c$ (A.7.4)

$\therefore \quad \frac{V}{b_w d} \le 69.6$ psi $\quad \frac{19.18^k}{(12'')(d)} \le 69.6$ psi

$d \ge 23.0''$

ASSUMES #10 BAR

$t \ge 23.0'' + 3''$ (SHEETPILE) $+ 2''$ (COVER) $+ \frac{1}{2}(10/8) = 28.6''$

SEE NEXT PAGE FOR FINAL

USE 2'-6" WALL

FOR CALCULATIONS INVOLVING BUOYANCY USE WALL THICKNESS = 2'-3"

FOR CALCULATIONS INVOLVING MOMENT USE $d = 24.4''$
(2'-6" - 3" (SHEETPILE) - 2" (COVER) - $\frac{1}{2}(10/8) = 24.4''$

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- BASED ON FLEXURE CHECK THE "d" PROVIDED BASED ON SHEAR WITH THE "d" REQ'D FOR FLEXURE

$$\text{REQ'D "d"} = \sqrt{\frac{2M}{f_c b k j}} \quad (P.6)$$

$$\left.\begin{array}{l} k = 3/8 \\ j = 7/8 \\ f_c = 1.80 \text{ ksi} \end{array}\right\} (P.6)$$

$$\text{REQ'D "d"} = \sqrt{\frac{2(118.9 \text{ ft-k})(12 \text{ in/ft})}{1.80 \text{ ksi}(12")(3/8)(7/8)}} = 20.1"$$

REQ'D "d" < "d" PROVIDED 20.1" < 24.4" (ok)

$$A_{s_{REQ'D}} = \frac{M}{f_s j d} = \frac{118.9 \text{ ft-k}(12"/ft)}{24 \text{ ksi}(7/8)(24.4)} = 2.78 \text{ in}^2$$

TRY #10 @ 6" $A_s = 2.54 \text{ in}^2$ $f_{s_{ALLOW}} = 25.8$ ksi $d = 24.4$

$$f_{s_{ACTUAL}} = \frac{118.9(12)}{2.54(7/8)(24.4)} = 26.3 \text{ ksi} \quad (\#10 @ 6 \text{ NG})$$

SEE #11@6" BELOW

TRY #8@4" OR #11@6" $A_s = 2.37 \text{ in}^2$ OR 3.12 in^2

#8@4" $A_s = 2.37 \text{ in}^2$ $f_{s_{ALLOW}} = 30.0$ ksi (ACI 350 FIG 2.6.7(b))

$$f_{s_{ACTUAL}} = \frac{118.9(12)}{2.37(7/8)(24.4)} = 28.2 \text{ ksi} \quad (ok)$$

#11@6" $A_s = 3.12 \text{ in}^2$ $f_{s_{ALLOW}} = 25.8$ ksi (ACI 350 FIG 2.6.7(c))

$$f_{s_{ACTUAL}} = \frac{118.9(12)}{3.12(7/8)(23.3)} = 22.4 \text{ ksi} \quad (ok)$$

NOTE: NEED $2\frac{13}{16}$" MIN. CLEAR - SEE P. 68
USE 3" CLEAR

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	
BY M DYE / J. Schmidt — CHECKED BY R DUNCAN	APPROVED BY — DATE 10/22/92

16.4 ft WALL

$$M_{200/f_y} = 24^{ksi}(0.92\,in^2)(7/8)(23.3")(1\,ft/12\,in) = 37.5^{'k}$$

DISTANCE DOWN WALL WHERE M_{200/f_y} OCCURS

$$37.5 = 0.431(x-2) + 0.287(x-3)(x-3/2) + 0.0527(x-3)^2(x-3/3) + 0.166x^2$$

$$x = 10.51\ ft$$

$$M_{ACT} = 118.9\ ft\cdot k \text{ @ } 16.4\ ft$$

FIND THE DISTANCE DOWN THE WALL WHERE THE WALL CAN BE DESIGNED FOR 4/3 M_{ACT}

$$37.5 = 1.33\left[(0.431)(x-2) + 0.287(x-3)(x-3/2) + 0.0527(x-3)^2(x-3/3) + 0.166x^2\right]$$

$$x = 9.37\ ft$$

I WANT TO KEEP ALL OF THE DOWEL SPACING @ 6" ∴
SPLICE #11 @ 6" W/ #8 @ 12" and #6 @ 12"

MUST ALTERNATE SPLICES

SPLICE #8 1.3(28.5') = 37.1" SAY 3'-2"
SPLICE #6 1.3(21.3') = 27.7" SAY 2'-4"

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DISTANCE DOWN WALL WHERE #6 @ 12" CAN BE USED

$f_s = 21.6$ ksi (ACI 350 FIG 2.6.7(b))

$A_s = 0.44\ in^2$

$d = 30 - 3 - 3 - \frac{1}{2}(1/8) = 23.3''$

$$21.6 = \frac{1.33\left[(0.431 \cdots\cdots)\right](12)}{0.44(7/8)(23.3)}$$

$x = 6.65$ ft

DISTANCE DOWN WALL WHERE #11 @ 12" AND #8 @ 12" CAN BE USED

$f_s = 25.8$ ksi (ACI 350 FIG 2.6.7(c)) (Bars @ 6" O.C., #11 MAX. SIZE)

$A_s = (1.56 + 0.79) = 2.35\ in^2$

$$25.8 = \frac{1.33\left[(0.431 \cdots\cdots)\right](12)}{2.35(7/8)(23.3)}$$

$x = 13.92$ ft (SEE SHEAR CHECK BELOW ⇒ $x = 12.50$

DISTANCE DOWN WALL WHERE #6 @ 12" AND #8 @ 12" CAN BE USED

$f_s = 27.3$ ksi (ACI 350 FIG 2.6.7(b)) (Bars @ 6" O.C.)

$A_s = (0.44 + 0.79) = 1.23\ in^2$

$$27.3 = \frac{1.33\left[(0.431 \cdots\cdots)\right](12)}{1.23(7/8)(23.3)}$$

$x = 11.07$ ft

ACI 318 12.10.5 CHECK

$V_s @ \overset{12.5}{\cancel{13.92}}\text{ ft} = 0.0527(\overset{12.5}{\cancel{13.92}} - 3)^2 + 0.619(\overset{12.5}{\cancel{13.92}}) - 0.4305 = \overset{12.06}{\cancel{14.47}}$ k

$v = \overset{12.06}{\cancel{14.47}}\text{ k} / (12)(23.3) = \overset{43.1}{\cancel{51.8}}$ psi Too High! Try 12.5' — OK

$\frac{2}{3} v_{c\,ALLOW} = 44.4$ psi (OK)

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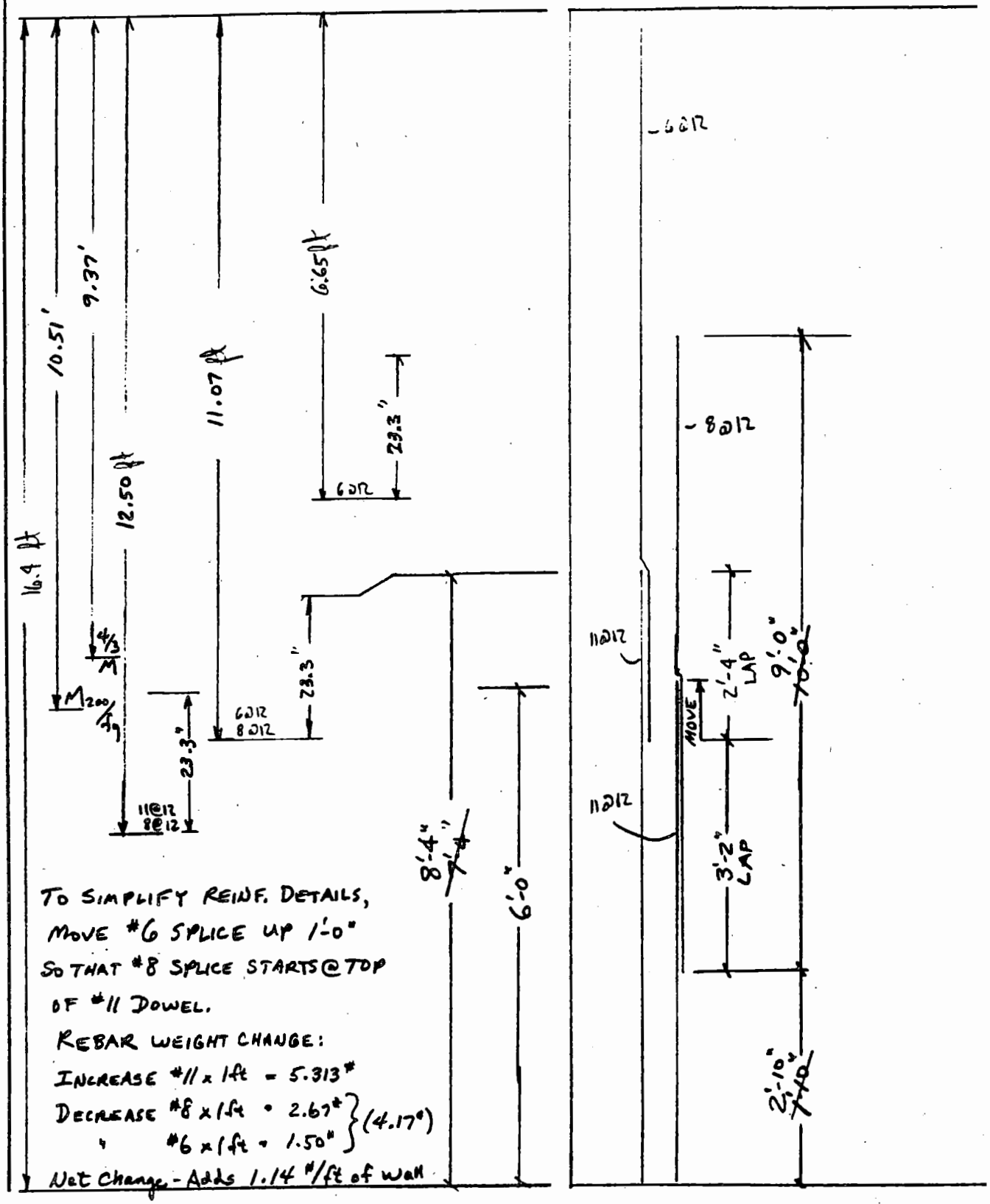


TO SIMPLIFY REINF. DETAILS,
MOVE #6 SPLICE UP 1'-0"
SO THAT #8 SPLICE STARTS @ TOP
OF #11 DOWEL.

REBAR WEIGHT CHANGE:

INCREASE #11 x 1ft = 5.313#

DECREASE #8 x 1ft = 2.67# } (4.17#)
" #6 x 1ft = 1.50#

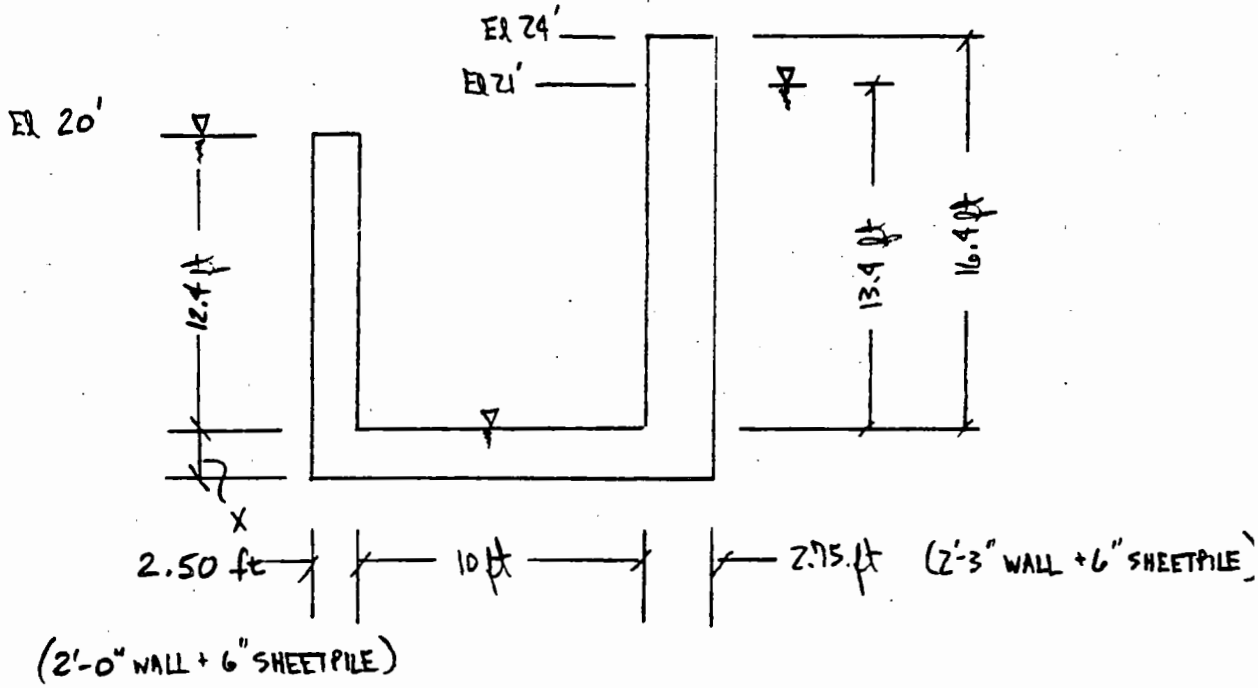
Net Change - Adds 1.14 #/ft of wall

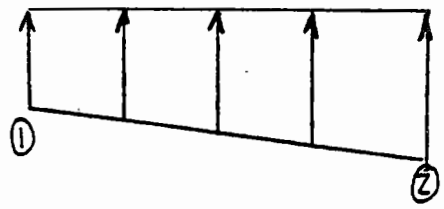
CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	
BY: M DYE / J. Schmehl — CHECKED BY: R DUNCAN	APPROVED BY / DATE: 10/22/92

DESIGN BOTTOM SLAB

THE 16.40 ft WALL RANGES FROM STA 7+00 TO STA 7+~~75~~ 73± ON THE RIGHT SIDE OF THE TRENCH

ON THE LEFT SIDE OF THE TRENCH FROM STA 7+00 TO STA 7+~~75~~ 73± THE BASIS FOR DESIGN IS A 13.2' ft WALL





PRESSURE @ 1 = 62.4 pcf (12.4 ft + x) = 774 + 62.4(x)

PRESSURE @ 2 = 62.4 pcf (13.9 ft + x) = 836 + 62.4 (x)

2 - 1 = 62.4 pcf

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$\downarrow \Sigma F = \uparrow \Sigma F$

$\downarrow \Sigma F = 2.50\,ft(12.4\,ft)(1\,ft)(.15\,kcf) + 2.75\,ft(16.4\,ft)(1\,ft)(.15\,kcf) + 15.25\,ft(1\,ft)(x)(.1$

$= 11.42^k + 2.288\,(x)$

$\uparrow \Sigma F = \left([774 + 62.4(x)]/1000\right)(1\,ft)(15.25\,ft) + \frac{1}{2}(62.4\,x)(1\,ft)(15.25\,ft)/1000$

$12.28^k + 0.952(x)$

$11.42^k + 2.288(x) = 12.28^k + 0.952\,(x)$

$x = 0.64\,ft$

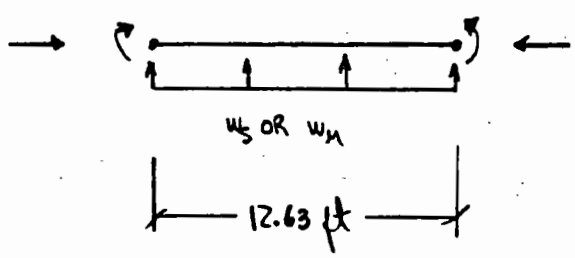
USE A WALL THICKNESS EQUAL TO THE THICKNESS OF THE 16.4 ft WA
DUE TO THE TRANSFER OF THE WALL MOMENT INTO THE BASE SLAB

CALCULATE THE MOMENT ON THE BASE SLAB

NET UPLIFT LOAD ACTING ON SLAB = WEIGHT WALLS / TRENCH WIDTH

$w_s = 11.42^k / 15.25\,ft = 0.75\,k/ft$

$w_u = 1.3(1.7)(w_s) = 1.65\,k/ft$



CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
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$M_{s_{POS}} = w_s l^2/8 = 0.75^k/ft(12.63\,ft)^2/8 = 14.95\ ft\cdot k$

$M_{u_{POS}} = w_u l^2/8 = 1.65^k/ft(12.63\,ft)^2/8 = 32.90\ ft\cdot k$

DUE TO DIFFERING WALL HEIGHTS AND LOADING CONDITIONS DETERMINE THE LOADS ACTING @ THE ℄ OF THE SLAB

<u>12.4 ft WALL</u>

$P_u = V_u(@\ x = 12.4' + 2'\text{-}6''\ SLAB = 14.9')$

(USED EQ. P 11)

$P_u = 1.3(1.7)(V_s\ @\ 14.9') = 35.8^k;\ V_s = 16.2^k$

$M_u = 1.3(1.7)(M_s\ @\ 13.65') = 163.3'^k;\ M_s = 73.9'^k$

<u>16.9 ft WALL</u>

$P_u = V_u(@\ x = 16.4' + 2'\text{-}6''\ SLAB = 18.9')$

$P_u = 1.3(1.7)(V_s\ @\ 18.9\ ft) = 54.4^k;\ V_s = 24.6^k$ (EQ P.84)

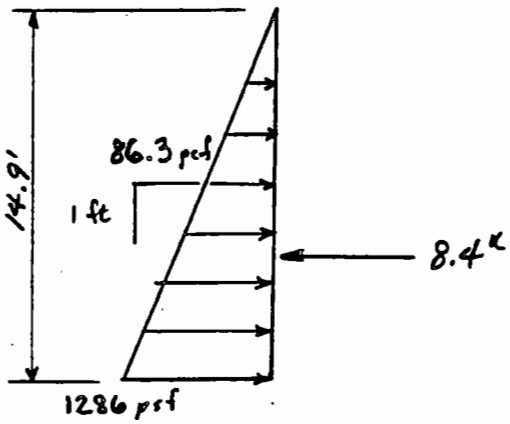
$M_u = 1.3(1.7)(M_s\ @\ 17.65') = 319.3'^k;\ M_s = 144.5\ ft\cdot k$ (P 83)

CLIENT Sun Oil		JOB NUMBER RC-0086	
SUBJECT Concrete Trench Design			
BASED ON		DRAWING NUMBER	
BY J. Schmoll	CHECKED BY R DUNCAN	APPROVED BY	DATE 11/19/92

16.4 ft. Wall on West Side vs. 12.4' Wall on East Side

Assume the difference in Slab Axial Loads will be taken by developing passive earth pressure against the 12.4' wall.

$$P_{s(16.4)} - P_{s(12.4)} = 24.6^k - 16.2^k = 8.4^k$$ Unbalanced Load per foot of wall



Passive Pressure Limit (Ref. Table 6.0-Soil Repo for Type "F-Dense" See Note Below

$$= (K_p - K_o)\,\gamma_b$$
$$= (2.03 - 0.66)(63\,pcf) = 86.3\ pc$$

$$R_{p\,max.} = 86.3\,pcf\,(H)\left(\tfrac{H}{2}\right)(1\,ft)$$
$$= 86.3(14.9)\left(\tfrac{14.9}{2}\right) = 9{,}580\ Lb$$
$$> 8{,}400\ Lb\ ($$

NOTE: The walls & bottom slabs have been designed on the basis of Stratum "F - Loose" Fill as the active and at-rest pressure combinations are higher for this assumption and hence somewhat conservative. However, the passive earth pressure given in Table 6.0 for "F-Loose" in report seems exceedingly conservative for the general case. With Reference to Boring B-37-5 near Sta. 8+00 (Table 3.0-Soil Repo the soils near the 14' depth appear to be "F-Dense", since the blow counts are relatively high. Assume "F-Dense" for passive resistance limit.

Add'l Moment @ Base of Wall due to passive pressure

$$M_p = 0.0863\,pcf\,(12.4)^3(1\,ft)/6 = 27.4'^k$$
$$M_s = 0.0169(12.4)^3 + 0.166(12.4)^2 = 57.7$$
$$85.1'^k \text{ vs. } 89.3'^k \text{ for } 13.2' \text{ Wall Design}$$

(See p. 67)

~~Use of 13.2' Wall Design OK for 12.4' Wall Above~~

See Next Page

CLIENT Sun Oil		JOB NUMBER RC-0086	
SUBJECT Concrete Trench Design			
BASED ON		DRAWING NUMBER	
BY J. Schmohl	CHECKED BY R DUNCAN	APPROVED BY	DATE 11/19/92

Add'l Shear @ Base of Wall Due to Passive Pressure

$V_p = 0.0863\ pcf\,(12.4')^2/2 = 6.63^k$

$V_s = 0.0507(12.4')^2 + 0.332(12.4') = 11.91$

$18.54^k > 16.73^k$ for 13.2 WALL DESIGN (

NO GOOD!

∴ Must use 16.4' Wall Design Both Sides of Trench!

SUN OIL - MCAP
OUR PROJECT NO. ML3626-20
JD 4/9/92

SUMMARY OF ADDITIONAL STABILIZATION REQUIRED
BENEATH THE CENTERLINE OF THE PROPOSED CONVEYANCE TRENCH

BORING NUMBER	APPROXIMATE STATION	APPROX. GROUND SURFACE ELEV.	MIN. DEPTH OF STABILIZATION BELOW GR. SURF. (FT)	MINIMUM ELEV. OF STABILIZATION	APPROX. PROPOSED FOUNDING ELEV.	ADD. DEPTH OF STABILIZATION BELOW FOUNDING (FT)
B-37-1	0+00	20	6	14	8	0
B-2-1 *	1+40	11	6	6	8	2
B-37-2	2+20	17	15	2	7	5
B-3-1 *	4+00	12	5	7	6	0
B-37-3	4+50	18	14	4	6	2
B-37-4	6+00	19	12	7	6	0
B-37-5	8+00	20	18	2	5	3
B-37-6	10+00	19	14	5	4	0
B-4-1 *	11+50	12	7	5	3	0
B-37-7	12+00	18	14	4	3	0
B-5-1 *	15+00	13	10	4	2	0
B-37-8	15+25	14	12	2	2	0
B-37-9	16+10	14	10	4	1	0
B-6-1 *	17+00	16	7	10	1	0
B-37-10	17+30	13	9	4	1	0
C-2-1 *	19+00	8	9	-1	0	1
B-37-11	19+00	11	12	-1	0	1
D-1-1 *	20+00	9	8	1	0	0
B-37-12	21+50	11	11	0	-1	0
D-2-1 *	21+50	10	9	2	-1	0
B-37-13	22+50	12	14	-3	-2	1
D-3-1 *	23+00	7	9	-2	-2	0
D-3-2 *	23+00	10	8	2	-2	0
B-37-14	25+00	12	15	-3	-3	0
B-37-15	27+00	9	7	2	-4	0
B-37-16	29+00	10	10	0	-5	0
B-37-17	30+75	11	12	-1	-5	0
E-1-1 *	33+00	13	6	7	-6	0
E-1-2 *	33+00	13	8	6	-6	0
B-37-18	33+00	11	12	-2	-6	0
B-37-19	35+00	11	15	-5	-7	0

* BORINGS COMPLETED AS PART OF PREVIOUS INVESTIGATION- HAND EQUIPMENT

TABLE 3.0

SITE engineers, inc.

TEST BORING LOG

PROJECT SUN OIL - MCAP
LOCATION MARCUS HOOK, PA

G.S ELEV 20.2
FILE ML 3626-20
SHEET 1 OF 1

GROUND WATER DATA			
FIRST ENCOUNTERED			
DEPTH	HOUR	DATE	ELAPSED TIME
4'	1230	4-2	15 MIN

METHOD OF ADVANCING BORE HOLE				
d	FROM	0	TO	2'
a	FROM	2'	TO	16'
d	FROM	16'	TO	33'
	FROM		TO	
	FROM		TO	

DRILLER L. DIFOLIO
HELPER R. ELLER
INSPECTOR G. MAYNOR
DATE STARTED 4-2-92
DATE COMPLETED 4-2-92

DEPTH	A	B	C	DESCRIPTION	REMARKS
				2' BROWN-GRAY SAND AND CRUSHED STONE (FILL)	
EL 16.2' ▽	S-1	3-4 5-5			
5	S-2	6-7 7-10	F	7' BLACK TO GRAY FINE TO MEDIUM SAND, FINE TO COARSE GRAVEL, COAL, TAR (FILL)	
	S-3	4-4 6-8		9'6 BROWN CLAYEY SILT, TRACE FINE FINE SAND (FILL)	
10	S-4	5-7 9-12			
	S-5	11-19 21-22		BROWN TO BLACK SAND, GRAVEL, SILT, WOOD, COAL, BRICK (FILL)	12'
	S-6	14-7 9-9		14'	
15	S-7	2-2 1-2	1B	GRAY SILTY CLAY, TRACE (OH) DECOMPOSED VEGETATION	
	U-1	24" REC		18'	4
20	S-8	7-9-9	1A	LIGHT GRAY TO GREEN CLAY, SOME SILT, TRACE FINE SAND (CL)	
				23'6	
25	S-9	5-7-11			
30	S-10	8-11-13	3	BROWN TO WHITE TO ORANGE BROWN SILT, TRACE ROCK FRAGMENTS, TRACE MICA FLAKES (DECOMPOSED ROCK) (ML)	
		50/0			EL -12.3
35				REFUSAL ON CUTTER HEAD AT 33'	B.O.T EL
40					
45					

3.5

FS

1010
5/26/92
BO. THICKN in @
-2 FT from BOA
1.8. of PIPE

FOR GENERAL NOTES SEE KEY SHEET AND LOCATION PLAN.

DRN. FEN
CKD. 40

E905 7/82

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmehl — CHECKED BY: R DUNCAN	APPROVED BY — DATE: 10/22/92

DESIGN THE BASE SLAB ON FLEXURE FROM THE 16.9 ft WALL

BOTTOM STEEL

$M_u = 319.3$ ft·k

← ASSUMES #11 BAR

$d = 2.5\text{ ft} - 3''(\text{cover}) - \frac{1}{2}(1\frac{1}{8}) = 26.3''$

$R_n = M_u/\phi b d^2 = \dfrac{319.3\text{ ft}\cdot\text{k}\,(12{,}000)}{0.9(12)(26.3)^2} = 512.9$ psi

$\rho = 0.0093$

$A_{s_{REQ'D}} = \rho b d = 0.0093(12'')(26.3'') = 2.94\text{ in}^2$

TRY #11 @ 6" $A_s = 3.12\text{ in}^2$

CHECK CRACKING

$f_{s_{ALLOW}} = 25.8$ ksi (ACI 350 FIG 2.6.7(c))

$f_{s_{ACTUAL}} = \dfrac{M_s}{A_s j d} = \dfrac{144.5\text{ ft}\cdot\text{k}\,(12\text{in}/\text{ft})}{3.12\text{ in}^2(7/8)(26.3'')} = 24.2$ ksi

$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ 24.2 ksi < 25.8 ksi (ok)

USE #11 @ 6"

TOP STEEL

Use #6 @ 12" (SEE P. 26)

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT: CONCRETE TRENCH DESIGN	
BASED ON: ACI 350-89 ALTERNATE DESIGN METHOD	DRAWING NUMBER
BY: M DYE / J. Schmoll — CHECKED BY: R DUNCAN	APPROVED BY — DATE: 10/22/92

$\rho = 0.0006$

$\rho_{min} = 200/F_y$ or 1.33ρ or 0.0018

$\rho_{REQ'D} = 0.0018$

$A_{s_{REQ'D}} = \rho bh = 0.0018(12'')(30'') = 0.65\ in^2$ EACH FACE

TRY #6 @ 12" $A_s = 0.49\ in^2$

CHECK CRACKING

$f_{s_{ALLOW}} = 21.6\ ksi$ (ACI 350 FIG. 2.6.1(b))

$f_{s_{ACTUAL}} = \dfrac{M_s}{A_s j d} = \dfrac{13.22(12)}{0.49(7/8)(26.4)} = 15.6\ ksi$

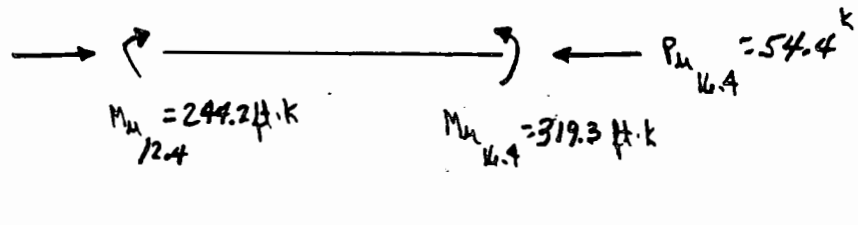
$f_{s_{ACTUAL}} < f_{s_{ALLOW}}$ $\quad 15.6\ ksi < 21.6\ ksi$ (ok)

USE #6 @ 12"

ANALYZE THE SLAB FOR BENDING AND AXIAL LOAD

(FOR INFO. ONLY)

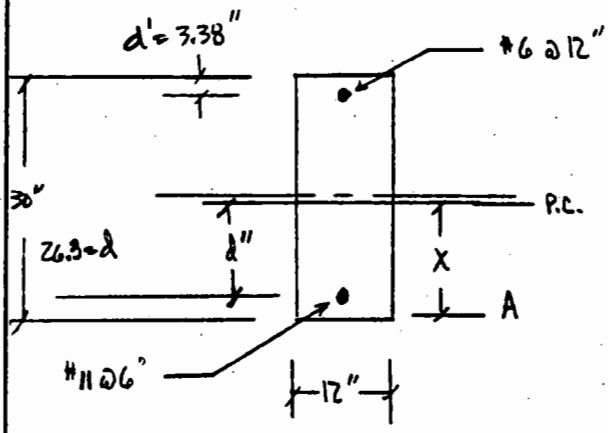
$M_u = 1.3(1.7)M_s = 1.3(1.7)(110.5'^k) = 244.2'^k$



$e_{12.4} = \dfrac{M_{u_{12.4}}}{P_{u_{12.4}}} = 53.9''$ $\qquad e_{16.4} = \dfrac{M_{u_{16.4}}}{P_{u_{16.4}}} = 70.4''$

CLIENT		JOB NUMBER	
SUN OIL		RC-0086	
SUBJECT			
CONCRETE TRENCH DESIGN			
BASED ON		DRAWING NUMBER	
ACI 350-89 ALTERNATE DESIGN METHOD			
BY M DYE	CHECKED BY R DUNCAN	APPROVED BY	DATE 10/22/92

THE GREATEST ECCENTRICITY (e) IS $e_{16.4}$. THEREFORE, ANALYZE THE SLAB USING THE LOADS FROM THE 16.4 ft WALL.



3" COVER TOP AND BOTTOM

$A_s = 3.12\ in^2$ $\quad A'_s = 0.44\ in^2$

FIND THE PLASTIC CENTROID

$C_1 = 0.85 f'_c (A_g - A_{st})$

$C_1 = 0.85(4)[(30 \times 12) - (3.12 + 0.44)]$

$C_1 = 1212^k$

$C_3 = A'_s f_y = 0.44(60) = 26.4^k$

$C_2 = A_s f_y = 3.12(60) = 187.2^k$

$$\Sigma M_A = 0 \; ; \quad x = \frac{1212^k(30/2) + 26.4^k(30 - 3.38) + 187.2^k(30 - 26.3)}{1212^k + 26.4^k + 187.2^k}$$

$x = 13.73''$

$d'' = 13.73'' - (30 - 26.3) = 10.03''$

DUE TO THE LARGE ECCENTRICITY (e) ASSUME TENSION CONTROLS

DETERMINE ALLOWABLE AXIAL LOAD @ BALANCED CONDITION

CLIENT	JOB NUMBER
SUN OIL	RC-0086
SUBJECT	
CONCRETE TRENCH DESIGN	
BASED ON	DRAWING NUMBER
ACI 350-89 ALTERNATE DESIGN METHOD	
BY M DYE / J. Schmoll — CHECKED BY RDUNCAN	APPROVED BY — DATE 10/22/92

$x_b = 87d / [87 + f_y] = 87(26.3)/[87+60] = 15.57''$

$C_c = 0.85 f'_c ab$ $\qquad a = \beta_1 x_b = 0.85(15.57'') = 13.23''$

$C_c = 0.85(4)(13.23)(12) = 539.8^k$

$T = A_s f_y = 3.12(60) = 187.2^k$

CHECK TO SEE IF COMPRESSION STEEL YIELDS

$$\epsilon'_s = 0.003\left(\frac{x_b - d'}{x_b}\right) = 0.003\left(\frac{15.57 - 3.38}{15.57}\right) = 0.0023$$

$\epsilon_y = 0.0021$

$\epsilon'_s > \epsilon_y$ COMPRESSION STEEL YIELDS

$C_s = A'_s(f_y - 0.85 f'_c) = 24.9^k$

$P_b = C_c + C_s - T = 539.8^k + 24.9^k - 187.2^k = 377.5^k$

$P_b e_b = C_c(d - a/2 - d'') + C_s(d - d' - d') + Td''$

$P_b e_b = 539.8(26.3 - 13.23/2 - 10.03) + 24.9(26.3 - 3.38 - 10.03) + 187.2(10.03)$

$P_b e_b = 7410$ k·in

$e_b = 7410$ k·in$/377.5^k = 19.63''$

$e > e_b$ (TENSION CONTROLS)