FILE: WALL  PROBA: A  CCNLLE WHZP SUBSET.CMS LEVEL 19

IF(ZL.25,XX) TES(KK),TSE(KK)
IF(XZ=5) W
XZ=1
XL=2
YZ=TOX(KK)
Z2=1+1


t=0(KK)

IF(XZ=5) TAU=T26

IF(XZ=5) XP=25
IF(XZ=5) TAU=K26
CALL P21(YZ,2,FLY,120,T26,XP,T26)

IF(XP.LT.XL OR XP.GT.X2) GO TO 73
TAU=TAU
GO TO 74
73 CONTINUE

IF(XP.LT.XL OR XP.GT.X2) GO TO 73
TAU=TAU
GO TO 74
74 CONTINUE

IF(XP.LT.XL OR XP.GT.X2) GO TO 73
TAU=TAU
GO TO 74
74 CONTINUE

10 CONTINUE

C

ALLOWABLE STRESS = YIELD POINT STRESS X 2.43

C

IF(IN.GG=1) ZMON/CA+G5
IF(IN.GG=2) ZMON/CA+G5
IF(IN.GG=3) ZMON/Z5
IF(IN.GG=4) ZMON/CA+G5

C

11 CONTINUE

C

IF(ZL.ISGZ) GO TO 10
GO TO 40
10 CONTINUE

C

IF(XL.GT.Z2) WORTE(+11,900)
IF(XL.GT.Z2) GO TO 50
GO TO 10
10 CONTINUE

C

IF(XL.GT.Z2) GO TO 50
GO TO 60

C

C

CONTINUE

40 CONTINUE

C

IF(IN.GG=1) W

C

END
FILE: WALL

FORMAT A

C
C SUMTF = 
SUMXY = 

C PERFORM REGRESSION ANALYSIS ON NAT. LOG OF DATA POINTS
C USE GAUSSIAN ELIMINATION

DO 2 I=1,N
WORK(I) = 
Y(I) = X(I) + 0.001
SUMX = SUMX + X
SUMY = SUMY + Y
SUMXY = SUMXY + X*Y
SUM2X = SUM2X + X**2
SUM2Y = SUM2Y + Y**2
YBAR = SUMY/N
XBAR = SUMX/N
2 CONTINUE

2 NAPX = SUMX/2, XBAR = XBAR
VARI = SUMX**2/NBAR - XBAR**2
SIGMA = SQRT(VARI/N)(M-1)

SLOPE = (SUMXY - M*SUMX)/(SUM2X - M*SUM2X)
CORR = SLOPE/SIGMA

WRITE(11,5) CORR

3 FORMAT(793 + CORRELATION = X.*F10.3)
WRITE(10,5) CORR

C SLOPE OF LOG-LOG CURVE = POWER OF DESIRED FUNCTION
THE Y-INT. OF THE LOG-LOG CURVE PRACTICALLY IS A POWER OF NAT. EXP.

C GIVES THE COEFF. OF DESIRED FUNCTION

DO 4 I=1,N
C(I) = X(I)**SLOPE
4 CONTINUE

WRITE(11,5) C(I)
WRITE(10,5) C(I)

5 FORMAT(793 + DATA POINTS, TSUMS, DIFFERENCE, TSUMS, DIFFERENCE)

C FORMAT(793 + DATA POINTS, TSUMS, DIFFERENCE, TSUMS, DIFFERENCE)

C 1980 FORMATION
C
C RETURN
END

SUBROUTINE POI(X1,X2,Y1,Y2, T1, T2, XP, TP)

SUBROUTINE TO FIND POINT OF INTERSECTION OF TWO LINES

X1 = Y2 - Y1 + (X2 - X1)
B1 = S1*X1 + Y1
S2 = S1*X1 + 1

RETURN
END
FILE: WALL  FORTRAN  A  CORNELL VM/SP SUBSET END LEVEL 10a

```fortran
ZD=(S2-B1)/(S1-72)  VAL03650
TP=(2*X+P+3)  VAL03690
RETURN  VAL03690
END

FUNCTION F1(XC,BET,BETA,THETA,PULL,PHI,T1,P1,P2,P)  VAL03650

SUBROUTINE TO INTERPOLATE DATA FROM REDUCTION CURVES FOR SAND  VAL03670

DIMENSION FAC(30,12),BET(12),TO(12)  VAL03670
DIMENSION P4(12)  VAL03670
S=XC/250.0  VAL03670
IF(ALPHA>5.0) GO TO 2  VAL03670
IF(ALPHA>10.0) GO TO 3  VAL03670
2 F1(ALPHA,-77)/.1  VAL03670
J=1  VAL03670
J=2  VAL03670
3 F1(ALPHA,-67)/.1  VAL03670
J=3  VAL03670
J=4  VAL03670
4 F1(ALPHA,-47)/.1  VAL03670
J=4  VAL03670
J=5  VAL03670
5 F1(ALPHA,-27)/.1  VAL03670
J=5  VAL03670
J=6  VAL03670
6 F1(ALPHA,-87)/.1  VAL03670
J=6  VAL03670
J=7  VAL03670
7 CONTINUE  VAL03670
DO 1 L=1,7  VAL03670
IF(ALPHA>5.0) GO TO 3  VAL03670
1 CONTINUE  VAL03670

SUBROUTINE TO INTERPOLATE DATA FROM REDUCTION CURVES FOR CLAY  VAL03670

DIMENSION FAC(30,12),BET(12),TO(12)  VAL03670
DIMENSION P4(12)  VAL03670
S=XC/250.0  VAL03670
IF(ALPHA>5.0) GO TO 2  VAL03670
IF(ALPHA>10.0) GO TO 3  VAL03670
2 F1(ALPHA,-77)/.1  VAL03670
J=1  VAL03670
J=2  VAL03670
3 F1(ALPHA,-67)/.1  VAL03670
J=3  VAL03670
J=4  VAL03670
4 F1(ALPHA,-47)/.1  VAL03670
J=4  VAL03670
J=5  VAL03670
5 F1(ALPHA,-27)/.1  VAL03670
J=5  VAL03670
J=6  VAL03670
6 F1(ALPHA,-87)/.1  VAL03670
J=6  VAL03670
J=7  VAL03670
7 CONTINUE  VAL03670
DO 1 L=1,7  VAL03670
IF(ALPHA>5.0) GO TO 3  VAL03670
1 CONTINUE  VAL03670
```
FILE: WALL

*TRAN 4

.CORPUS VM/SP SUBSET CMS LEVEL 104

12 IF (T.ST.31) GO TO 10
10 IF (J.EQ.13) GO TO 13
13 WRITE(1,220)
14 CALL FITDATA(SLOPE,TINT,K)
15 FORMAT(TDB,CURVE-FITTING FOR FILE MEMBERS/*))
16 RETURN

C
C SUBROUTINE CANTFAC(FLPCALPHA,MAX,TOP,FRAN,MOLFR)
C
C SUBPROGRAM TO INTERPOLATE DATA FROM REDUCTION CURVE FOR
C CANTELEDGE WALLS

C
C DIMENSION FAC(30,30),BET(6127,30,30)
C
C DIMENSION PHIC(120)
C
C IF(ALPHA.61) GO TO 4
C IF(ALPHA.64) GO TO 9
C IF(ALPHA.66) GO TO 6
C IF(ALPHA.67) GO TO 1
C IF(ALPHA.68) GO TO 2
C IF(ALPHA.69) GO TO 3
C IF(ALPHA.70) GO TO 5
C IF(ALPHA.71) GO TO 4
C IF(ALPHA.72) GO TO 3
C IF(ALPHA.73) GO TO 2
C IF(ALPHA.74) GO TO 1
C IF(ALPHA.75) GO TO 0
C IF(ALPHA.76) GO TO -1
C IF(ALPHA.77) GO TO -2
C IF(ALPHA.78) GO TO -3
C IF(ALPHA.79) GO TO -4
C IF(ALPHA.80) GO TO -5
C IF(ALPHA.81) GO TO -6
C IF(ALPHA.82) GO TO -7
C IF(ALPHA.83) GO TO -8
C IF(ALPHA.84) GO TO -9
C IF(ALPHA.85) GO TO -10
C IF(ALPHA.86) GO TO -11
C IF(ALPHA.87) GO TO -12
C IF(ALPHA.88) GO TO -13
C IF(ALPHA.89) GO TO -14
C IF(ALPHA.90) GO TO -15
C IF(ALPHA.91) GO TO -16
C IF(ALPHA.92) GO TO -17
C IF(ALPHA.93) GO TO -18
C IF(ALPHA.94) GO TO -19
C IF(ALPHA.95) GO TO -20
C IF(ALPHA.96) GO TO -21
C IF(ALPHA.97) GO TO -22
C IF(ALPHA.98) GO TO -23
C IF(ALPHA.99) GO TO -24
C IF(ALPHA.100) GO TO -25
C IF(ALPHA.101) GO TO -26
C IF(ALPHA.102) GO TO -27
C IF(ALPHA.103) GO TO -28
C IF(ALPHA.104) GO TO -29
C IF(ALPHA.105) GO TO -30
C IF(ALPHA.106) GO TO -31
C IF(ALPHA.107) GO TO -32
C IF(ALPHA.108) GO TO -33
C IF(ALPHA.109) GO TO -34
C IF(ALPHA.110) GO TO -35
C IF(ALPHA.111) GO TO -36
C IF(ALPHA.112) GO TO -37
C IF(ALPHA.113) GO TO -38
C IF(ALPHA.114) GO TO -39
C IF(ALPHA.115) GO TO -40
C IF(ALPHA.116) GO TO -41
C IF(ALPHA.117) GO TO -42
C IF(ALPHA.118) GO TO -43
C IF(ALPHA.119) GO TO -44
C IF(ALPHA.120) GO TO -45
C
C 2 CONTINUE

C
C
APPENDIX C

SAMPLE OUTPUT

Site Geometry and Soil Parameters

The geometric and soil parameters are listed in the output to provide a check. This output should be checked first when debugging.

Factored Soil Parameters

Factored soil parameters are used to compute the following in each soil layer:

- Depth of soil layer interface (from top of wall)
- Active and passive stress coefficients
- Effective unit weight
- Triangular stress distribution (overburden and horizontal)
- Rectangular stress distribution (overburden and horizontal)
- Resultant force for each stress distribution
- Centroid for each stress distribution
- Moment arm for each stress distribution
- Resultant moment for each stress distribution

Depth of Penetration

The required penetration depth is printed out. If the subgrade cohesion renders an unstable wall, a message reading "THIS WALL CANNOT STAND" will appear and the program will terminate. The stability number of factor of safety against failure in penetration are listed for cohesive subgrades.

Unfactored Soil Parameters

A listing appears of the same parameters output for "Factored Soil Parameters," the difference being that this listing is computed for tie-rods loads and bending moments using unfactored soil parameters.

Tie-Rod Load

The tie-rod load is listed in lb/ft of wall.
Maximum Moment

The maximum bending moment, as computed by the Free Earth Support method is displayed. The location of the maximum moment is also shown (point of zero shear).

Operating and Structural Curves

Ordered pairs of $\tau$ and $\log \rho$ are shown for A328 steel sections, A570/A690 steel sections, and wood piles. Ordered pairs are first given for typical sections, then the actual design section. Curve-fitting data is given for clay subgrades where there are only three values of pile flexibility given in the Rowe reduction curves. The value of representing the point of intersection of the operating and structural curves is shown.

Design Section Modulus

The results of the Rowe reduction procedure are listed in $\text{in}^3/\text{ft}$ of wall for A328 steel, A570/A690 steel and timber.

Design Section

The final USS section is listed for A328 steel, A570/A690 steel, as well as the required actual thickness for a timber pile. The tie-rod load is also output.
### Soil Layer Information

<table>
<thead>
<tr>
<th>Soil Layer</th>
<th>Depth (ft)</th>
<th>Unit Weight (pcf)</th>
<th>PSI</th>
<th>Cohesion (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.000</td>
<td>100.000</td>
<td>30.000</td>
<td>0.000</td>
</tr>
<tr>
<td>2</td>
<td>12.000</td>
<td>122.400</td>
<td>32.000</td>
<td>0.000</td>
</tr>
<tr>
<td>3</td>
<td>100.000</td>
<td>122.400</td>
<td>32.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**Wall Height**: 12.00 ft  
**Low Water**: 8.00 ft  
**Excavation**: 10.00 ft  
**Surcharges**: 200 psf (distributed load)  
**Centroids**: N/A  
**Dredge Slope**: 4.00 degrees

### Anchored Bulkhead

<table>
<thead>
<tr>
<th>Zer.</th>
<th>KP</th>
<th>KA</th>
<th>Gamma</th>
<th>Forces</th>
<th>Moment Arms</th>
<th>Moment N maintain</th>
</tr>
</thead>
</table>

**Factor of Safety**: 1.10  
**Depth of Penetration**: 6.10 ft

### Typical Section

<table>
<thead>
<tr>
<th>Lug Pipe</th>
<th>Lug Rod</th>
<th>Lug Nut</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.750</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>1.200</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>1.500</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>1.800</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>2.100</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>2.400</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>2.700</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>3.000</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>3.300</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>3.600</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>3.900</td>
<td>2.838</td>
<td>0.64</td>
</tr>
<tr>
<td>4.200</td>
<td>2.838</td>
<td>0.64</td>
</tr>
</tbody>
</table>
### A572/690 Steel Operating and Structural Curves

**Specific Section**

<table>
<thead>
<tr>
<th>LEO</th>
<th>THO</th>
<th>TO</th>
<th>TS</th>
<th>FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.600</td>
<td>2.953</td>
<td>2.494</td>
<td>2.302</td>
<td></td>
</tr>
<tr>
<td>-1.600</td>
<td>2.953</td>
<td>2.494</td>
<td>2.302</td>
<td></td>
</tr>
<tr>
<td>-2.000</td>
<td>3.039</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-2.100</td>
<td>3.115</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-2.200</td>
<td>3.191</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-2.300</td>
<td>3.267</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-2.400</td>
<td>3.343</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-2.500</td>
<td>3.419</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-2.600</td>
<td>3.495</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-2.700</td>
<td>3.571</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-2.800</td>
<td>3.647</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-3.000</td>
<td>3.807</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-3.100</td>
<td>3.967</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-3.200</td>
<td>4.127</td>
<td>2.953</td>
<td>2.494</td>
<td></td>
</tr>
<tr>
<td>-3.300</td>
<td>4.287</td>
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<td>2.494</td>
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</tr>
<tr>
<td>-3.400</td>
<td>4.447</td>
<td>2.953</td>
<td>2.494</td>
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<tr>
<td>-3.500</td>
<td>4.607</td>
<td>2.953</td>
<td>2.494</td>
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</tr>
</tbody>
</table>

**TAU = 3.465**

### Mild Operating and Structural Curves

**Typical City**

<table>
<thead>
<tr>
<th>LEO</th>
<th>THO</th>
<th>TO</th>
<th>TS</th>
<th>FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.100</td>
<td>2.234</td>
<td>2.043</td>
<td>2.302</td>
<td></td>
</tr>
<tr>
<td>-1.100</td>
<td>2.234</td>
<td>2.043</td>
<td>2.302</td>
<td></td>
</tr>
</tbody>
</table>

**TAU = 2.483**
CALCULATED SECTION MODULUS: 1,358 in.³ (3388)
6,476 in.³ (972,600)
7,746 in.³ (1566)

SECTION MATERIAL SEC ROD NW/MFTY DEPTH/MON TIE-ROD PULL

<table>
<thead>
<tr>
<th></th>
<th>(IN³-1)</th>
<th>(IN²-1)</th>
<th>(IN-LB/Ft)</th>
<th>(LBS/Ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ps 25</td>
<td>424</td>
<td>1.9</td>
<td>254</td>
<td>141</td>
</tr>
<tr>
<td>Ps 25</td>
<td>620/760</td>
<td>1.9</td>
<td>254</td>
<td>141</td>
</tr>
<tr>
<td>WOOD PILE THICKNESS 14 IN</td>
<td>2.22</td>
<td>2.2</td>
<td>195</td>
<td>195</td>
</tr>
</tbody>
</table>

CANTILEVERED BULKHEAD

FACTORED SOIL PARAMETERS

<table>
<thead>
<tr>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

UNFACTORED SOIL PARAMETERS

<table>
<thead>
<tr>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

GROUT OF PILE: 15.60 FT
### A328 Steel Operating and Structural Curves

#### Typical Section

| LUG PHO | -1.000 | TD | 3.918 | TS | 0.375 |
| LUG RHD | -1.250 | TD | 3.918 | TS | 0.543 |
| LUG RHO | -1.500 | TD | 3.918 | TS | 0.600 |
| LUG PHO | -1.750 | TD | 3.918 | TS | 0.789 |
| LUG RHD | -2.000 | TD | 4.123 | TS | 2.055 |
| LUG RHO | -2.250 | TD | 4.306 | TS | 3.751 |
| LUG PHO | -2.500 | TD | 4.712 | TS | 5.586 |
| LUG RHD | -2.750 | TD | 5.174 | TS | 6.863 |
| LUG RHO | -3.000 | TD | 5.637 | TS | 11.061 |
| LUG PHO | -3.250 | TD | 5.993 | TS | 17.910 |
| TAU | 4.407 |

#### Specific Section

| LUG PHO | -1.000 | TD | 3.918 | TS | 0.375 |
| LUG RHD | -1.250 | TD | 3.918 | TS | 0.543 |
| LUG RHO | -1.500 | TD | 3.918 | TS | 0.600 |
| LUG PHO | -1.750 | TD | 3.918 | TS | 0.789 |
| LUG RHD | -2.000 | TD | 4.123 | TS | 2.055 |
| LUG RHO | -2.250 | TD | 4.306 | TS | 3.751 |
| LUG PHO | -2.500 | TD | 4.712 | TS | 5.586 |
| LUG RHD | -2.750 | TD | 5.174 | TS | 6.863 |
| LUG RHO | -3.000 | TD | 5.637 | TS | 11.061 |
| LUG PHO | -3.250 | TD | 5.993 | TS | 17.910 |
| TAU | 4.723 |

### A327/438 Steel Operating and Structural Curves

#### Typical Section

| LUG PHO | -1.000 | TD | 3.918 | TS | 0.375 |
| LUG RHD | -1.250 | TD | 3.918 | TS | 0.543 |
| LUG RHO | -1.500 | TD | 3.918 | TS | 1.142 |
| LUG PHO | -1.750 | TD | 3.918 | TS | 2.060 |
| LUG RHD | -2.000 | TD | 3.918 | TS | 3.311 |
| LUG RHO | -2.250 | TD | 3.918 | TS | 3.311 |
| LUG PHO | -2.500 | TD | 3.918 | TS | 2.977 |
| LUG RHD | -2.750 | TD | 3.918 | TS | 11.419 |
| LUG RHO | -3.000 | TD | 3.918 | TS | 16.376 |
| LUG PHO | -3.250 | TD | 3.918 | TS | 28.600 |
| LUG RHD | -3.500 | TD | 3.918 | TS | 16.116 *
| TAU | 4.723 *

#### Specific Section

| LUG PHO | -1.000 | TD | 3.918 | TS | 0.375 |
| LUG RHD | -1.250 | TD | 3.918 | TS | 0.543 |
| LUG RHO | -1.500 | TD | 3.918 | TS | 1.289 |
| LUG PHO | -1.750 | TD | 3.918 | TS | 1.289 |
| LUG RHD | -2.000 | TD | 3.918 | TS | 1.289 |
| LUG RHO | -2.250 | TD | 3.918 | TS | 2.661 |
| LUG PHO | -2.500 | TD | 4.123 | TS | 2.661 |
| LUG RHD | -2.750 | TD | 4.123 | TS | 2.661 |
| LUG RHO | -3.000 | TD | 4.123 | TS | 2.661 |
| LUG PHO | -3.250 | TD | 4.123 | TS | 2.661 |
| TAU | 2.426 |
| LUG RHO = -2.500 T0 = 4.506 TS = 5.726 |
| LUG PHO = -2.750 T0 = 5.772 TS = 6.479 |
| LUG RHO = -3.000 T0 = 5.121 TS = 12.445 |
| LUG RHO = -3.250 T0 = 5.451 TS = 16.267 |
| LUG RHO = -3.500 T0 = 5.783 TS = 26.612 |
| TAU = 4.193 |

**WOOD OPERATING AND STRUCTURAL CURVES**

**TYPICAL SECTION**

| LUG RHO = -1.000 T0 = 3.910 TS = 8.567 |
| LUG RHO = -1.250 T0 = 3.910 TS = 8.568 |
| LUG RHO = -1.500 T0 = 3.910 TS = 8.568 |
| LUG RHO = -1.750 T0 = 3.910 TS = 8.563 |
| LUG RHO = -2.000 T0 = 3.997 TS = 2.876 |
| LUG RHO = -2.250 T0 = 4.123 TS = 3.194 |
| LUG RHO = -2.500 T0 = 4.306 TS = 4.480 |
| LUG RHO = -2.750 T0 = 4.772 TS = 6.482 |
| LUG RHO = -3.000 T0 = 5.134 TS = 18.191 |
| LUG RHO = -3.250 T0 = 5.431 TS = 14.826 |
| LUG RHO = -3.500 T0 = 5.993 TS = 21.762 |
| TAU = 4.252 |

**CALCULATED SECTION MODULUS**: 6.0E+6 (A328)

<table>
<thead>
<tr>
<th>SECTION</th>
<th>MATERIAL</th>
<th>SECTION</th>
<th>SECTION</th>
<th>DESIGN</th>
<th>TIE-ROD PULL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDA 27</td>
<td>A328</td>
<td>10.7</td>
<td>35.0</td>
<td>9476</td>
<td>0.2</td>
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<tr>
<td>PDA 27</td>
<td>0.50E+6</td>
<td>3.4</td>
<td>0.47</td>
<td>0.11</td>
<td>0.0</td>
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</tbody>
</table>

**WOOD PILE THICKNESS (IN)**: 4.13

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**APPENDIX D: FLOW TABLES FOR DESIGN**

Table D-1. Preliminary actions

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Reference Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establish soil profile</td>
<td>4.2</td>
</tr>
<tr>
<td>2</td>
<td>Determine bulkhead type (fill or dredge, anchored or cantilevered) and geometry, i.e., wall height, anchor level, dredge level, high and low water levels</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Determine soil parameters for each soil layer ($\phi$, $c$, $y$)</td>
<td>4.2</td>
</tr>
<tr>
<td>4</td>
<td>Compute soil stress coefficients using factored soil parameters ($\phi'$, $c'$) for penetration depth and unfactored ($\phi$, $c$) for tie-rod and moment calculations</td>
<td>2.3.1, Eq. 2-2, 2-3; 4.3</td>
</tr>
<tr>
<td>5</td>
<td>Compute stability number for walls in clay</td>
<td>4.5, Eq. 4-17</td>
</tr>
<tr>
<td>6</td>
<td>Produce a soil stress diagram to aid in calculations</td>
<td>4.3.1, 4.5</td>
</tr>
<tr>
<td>Step</td>
<td>Action</td>
<td>Reference Section</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
<td>-------------------</td>
</tr>
<tr>
<td>1</td>
<td>Compute soil stresses, resultant forces, centroids sum moments about</td>
<td>4.3.1</td>
</tr>
<tr>
<td></td>
<td>a. Tie-rod (anchored walls in sand)</td>
<td>4.5.1</td>
</tr>
<tr>
<td></td>
<td>b. Tie-rod (anchored walls in clay)</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>c. Pile toe (cantilevered walls in sand)</td>
<td>4.5.3</td>
</tr>
<tr>
<td></td>
<td>d. Pile toe (cantilevered walls in clay)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Solve for penetration depth, D, using factored soil parameters for</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Anchored walls in sand</td>
<td>4.3.1</td>
</tr>
<tr>
<td></td>
<td>b. Anchored walls in clay</td>
<td>4.5.1</td>
</tr>
<tr>
<td></td>
<td>c. Cantilevered walls in sand</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>d. Cantilevered walls in clay</td>
<td>4.5.3</td>
</tr>
<tr>
<td>3</td>
<td>Compute tie-rod pull, P (force per unit length of wall) by summing moments about</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. 2/3D (anchored walls in sand)</td>
<td>4.3.1</td>
</tr>
<tr>
<td></td>
<td>b. 1/2D (anchored walls in clay)</td>
<td>4.5.1</td>
</tr>
<tr>
<td>4</td>
<td>Find point of zero shear for:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Anchored walls</td>
<td>4.3.1, 4.5.1</td>
</tr>
<tr>
<td></td>
<td>b. Cantilevered walls</td>
<td>4.4</td>
</tr>
<tr>
<td>5</td>
<td>Compute maximum bending moment at point of zero shear</td>
<td>4.3.1, 4.5.1</td>
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<td></td>
<td></td>
<td>4.4</td>
</tr>
</tbody>
</table>
Table D-3. Rowe reduction calculations

<table>
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<tr>
<th>Step</th>
<th>Action</th>
<th>Reference Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compute $M_{\text{max}}$ from FES maximum moment</td>
<td>4.3.1, 4.4, 4.5.1</td>
</tr>
<tr>
<td>2</td>
<td>Develop an operating curve based upon $M_{\text{max}}$ and moment reduction factors for</td>
<td>4.3.1, 4.4, 4.5.1, 2.7.4, Fig. 2-17a, Fig. 2-19a, 2.7.6, Fig. 2-20</td>
</tr>
<tr>
<td></td>
<td>a. Anchored walls in sand</td>
<td>4.3.1</td>
</tr>
<tr>
<td></td>
<td>b. Anchored walls in clay</td>
<td>4.5.1</td>
</tr>
<tr>
<td></td>
<td>c. Cantilevered walls in sand</td>
<td>4.4</td>
</tr>
<tr>
<td>3</td>
<td>Develop structural curves based upon the average properties of the sheet pile material under consideration</td>
<td>4.3.1, 4.4, 4.5.1, 2.7.4, Fig. 2-17a, Fig. 2-19a, 2.7.6, Fig. 2-20</td>
</tr>
<tr>
<td>4</td>
<td>Find $T$ from the intersection of the operating and structural curves</td>
<td>4.3.1, 4.4, 4.5.1, 2.7.1.3, Fig. 2-18</td>
</tr>
<tr>
<td>5</td>
<td>Determine the member size from $T$</td>
<td>4.3.1, 4.4, 4.5.1</td>
</tr>
<tr>
<td>6</td>
<td>Recompute the structural curve based upon the properties of the selected section</td>
<td>4.3.1, 4.4, 4.5.1</td>
</tr>
<tr>
<td>7</td>
<td>Repeat steps 4 and 5 to insure that the selected section is adequate</td>
<td>4.3.1, 4.4, 4.5.1</td>
</tr>
<tr>
<td>8</td>
<td>Apply tie-rod factors</td>
<td>4.3.1, 2.3.7.1, Fig. 2-17b</td>
</tr>
<tr>
<td></td>
<td>a. Walls in sand</td>
<td>4.5.1, 2.7.4, Fig. 2-19b</td>
</tr>
<tr>
<td></td>
<td>b. Walls in clay</td>
<td>2.7.1.3, Fig. 2-17c</td>
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Table D-4. Computations for simplified procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Reference Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compute loading ratio, $R$</td>
<td>4.6</td>
</tr>
<tr>
<td>2</td>
<td>Compute modifying coefficient for depth, $C_D$</td>
<td>4.6</td>
</tr>
<tr>
<td>3</td>
<td>Compute $R_D = R \times C_D$, find dimensionless depth, $D'$ from design charts or equations</td>
<td>4.6</td>
</tr>
<tr>
<td>4</td>
<td>Compute $D = D' \times H$</td>
<td>4.6</td>
</tr>
<tr>
<td>5</td>
<td>Compute modifying coefficient for moment and tie-rod pull, $C_M = C_P$</td>
<td>4.6</td>
</tr>
<tr>
<td>6</td>
<td>Compute $R_M = R \times C_M$, find dimensionless bending moment, $M'$, from charts or equation</td>
<td>4.6</td>
</tr>
<tr>
<td>7</td>
<td>Compute moment $M = M' \gamma_3 L^3$</td>
<td>4.6</td>
</tr>
<tr>
<td>8</td>
<td>Compute $R_p = R \times C_P$, find dimensionless tie-rod pull, $P'$</td>
<td>4.6</td>
</tr>
<tr>
<td>9</td>
<td>Compute pull, $P = P' \gamma L^2$</td>
<td>4.6</td>
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</table>
Table D-5. Component design computations

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Reference Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Design tie-rod</td>
<td>5.4.2</td>
</tr>
<tr>
<td></td>
<td>a. Compute tie-rod tension based on pull per unit length of wall times the tie-rod spacing</td>
<td>5.4.2, 5.2.6</td>
</tr>
<tr>
<td></td>
<td>b. Apply load factors</td>
<td>5.4.2</td>
</tr>
<tr>
<td></td>
<td>c. Compute required diameter</td>
<td>5.4.2, 5.3.2</td>
</tr>
<tr>
<td></td>
<td>d. Determine length based on anchorage location</td>
<td>5.4.2, 5.3.2</td>
</tr>
<tr>
<td>2</td>
<td>Wale design</td>
<td>5.4.3</td>
</tr>
<tr>
<td></td>
<td>a. Compute bending moment in wale</td>
<td>5.4.3</td>
</tr>
<tr>
<td></td>
<td>b. Dimension the wale</td>
<td>5.4.3</td>
</tr>
<tr>
<td>3</td>
<td>Fastening wales to sheet piles</td>
<td>5.4.3.3</td>
</tr>
<tr>
<td></td>
<td>a. Inside wales, wood: select a nail size and determine the number of nails required per section to resist the prying force, P (tie-rod pull/unit length of wall)</td>
<td>5.4.3.1</td>
</tr>
<tr>
<td></td>
<td>b. Outside wales, wood: use 2 nails/pile. Select nail size with adequate length to transmit shear</td>
<td>5.4.3.1</td>
</tr>
<tr>
<td></td>
<td>c. Inside wales, steel</td>
<td>5.4.3.3</td>
</tr>
<tr>
<td></td>
<td>1) Select a bolt size and determine the number of bolts required to resist the prying force, P (tie-rod pull/unit length of wall)</td>
<td>5.4.3.3</td>
</tr>
<tr>
<td></td>
<td>2) Compute tensile force in each bolt</td>
<td>5.4.3.3</td>
</tr>
<tr>
<td></td>
<td>3) Compute bending moment in fixing plate</td>
<td>5.4.3.3</td>
</tr>
<tr>
<td></td>
<td>4) Dimension the fixing plate</td>
<td>5.4.3.3</td>
</tr>
<tr>
<td></td>
<td>d. Outside wale, steel: use number of bolts required to facilitate construction</td>
<td>5.4.3.3</td>
</tr>
<tr>
<td>Step</td>
<td>Action</td>
<td>Reference Section</td>
</tr>
<tr>
<td>------</td>
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<td>------------------</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td><strong>Splices for wales</strong></td>
<td></td>
</tr>
<tr>
<td>a. Outside wales, wood:</td>
<td>locate splices at the tie-rod. Design a bearing plate for the tie-rod nut</td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>b. Inside wales, wood:</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>1) Select splice plate dimensions (2- or 3-member splice) to resist maximum moment in wale</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>2) Select bolt size and number to resist shear</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>3) Determine edge distance, end distance, spacing between bolts, and spacing between rows</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>4) Select final length of splice plate</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>c. Splices for channels</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>1) Select splice plate width and thickness to fit between the channel flanges and to resist maximum moment in the wale</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>2) Select bolts to resist shear (double shear as bolts will attach 2 plates, one on each channel)</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>3) Allow for edge distance and spacing</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>4) Select a convenient length</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td><strong>Anchorage design</strong></td>
<td></td>
</tr>
<tr>
<td>a. Determine loads on:</td>
<td></td>
<td>5.4.3.2</td>
</tr>
<tr>
<td>1) Continuous anchorage</td>
<td></td>
<td>5.4.4.1</td>
</tr>
<tr>
<td>2) Short deadman</td>
<td></td>
<td>5.4.4.2</td>
</tr>
<tr>
<td>b. Check bearing stress of tie-rod nut and design a bearing plate, if required</td>
<td></td>
<td>5.4.3.2</td>
</tr>
</tbody>
</table>
EXAMPLE 1: GIVEN THE FOLLOWING SITE GEOMETRY AND SOIL CONDITIONS, FIND THE PENETRATION DEPTH, BENDING MOMENT AND TIE-ROD PULL USING THE FREE EARTH SUPPORT METHOD WITH ROWE REDUCTION:

\[ H = 12' \quad t_1 = 4' \quad g = 100 \text{ psf} \quad \beta_1 = 30^\circ \quad (\text{FIG. 4-1}) \]
\[ H_w = 8' \quad t_2 = 6' \quad g_2 = 122.4 \text{ psf} \quad \beta_3 = 32^\circ \]
\[ H_a = 7' \quad g_3 = 122.4 \text{ psf} \quad \beta_3 = 32^\circ \]

1) FIND FACTORED AND UNFACTORED SOIL PARAMETERS

\[ q_1 = 30^\circ \quad q_{1_f} = \tan^{-1}\left(\frac{1}{3} \tan 30^\circ \right) = 21^\circ \quad (\text{EQ 3-1}) \]
\[ q_2 = 32^\circ \quad q_{2_f} = 22.6^\circ \times 3 = 68^\circ \]
\[ \delta_1 = 20^\circ \quad \delta_{1_f} = 19^\circ \times 3 = 57^\circ \]
\[ \delta_2 = 21.3^\circ \quad \delta_{2_f} = 19^\circ \times 3 = 57^\circ \]

\[ K_a = \frac{\cos^2 q}{\left[1 + \frac{\sin(q - \delta) \sin q}{\cos \delta} \right]^2} \quad (\text{EQ 2-2}) \]
\[ K_p = \frac{\cos^2 q}{\left[1 - \frac{\sin(q - \delta) \sin q}{\cos \delta} \right]^2} \quad (\text{EQ 2-3}) \]

FACTORED:
\[ K_{a_f} = 0.403 \quad K_{p_f} = 3.00 \]

UNFACTORED:
\[ K_{a_f} = 0.279 \quad K_{p_f} = 5.74 \]

\[ \gamma_2 = 22.4 - 0.40 \text{ psf} = 21.0 \quad (\text{SOIL UNIT WEIGHT}) \]
2) **Compute Resultant Forces and Sum Moments About Tie Rod** (Fig. 4-2, Eq. 4-3)

\[
\begin{align*}
&\frac{1}{2} K a_3 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) + \frac{1}{2} K a_4 Y_4 \frac{2}{3} (\frac{2}{3} a_3 - a_4) + K a_3 Y_3 \frac{4}{3} (\frac{4}{3} a_2 + a_3) + K a_2 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) \\
&\frac{1}{2} K a_3 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) + K a_3 Y_3 \frac{4}{3} (\frac{4}{3} a_2 + a_3) + K a_2 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4)
\end{align*}
\]

\[
Y_3 D^2 (\frac{2}{3} D + a_3) = 0
\]

\[
218 - 9380 - 7380 + 33600 = (148 - 861) D^2 + 881 D^3 = 0
\]

\[
12,930 - 33600 - 713 D^2 - 881 D^3 = 0
\]

\[D = 5.6\]

3) **Compute Toe Shear Based Upon** \(W = H = D = 17.4\)

\[
(FT_1 - FT_2 + FR_1 + FR_2 - FT_3 - FT_4) \tan \theta = (Eq. 4-2)
\]

\[
\begin{align*}
&\frac{1}{2} K a_3 Y_3 \frac{4}{3} (\frac{4}{3} a_2 + a_3) - \frac{1}{2} K a_2 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) + K a_3 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) + K a_3 Y_3 \frac{4}{3} (\frac{4}{3} a_2 + a_3) \\
&- \frac{1}{2} (K a_4 - K a_3) Y_3 D^2 \tan \theta,
\end{align*}
\]

\[
(320 + 120 + 1880 - 2760) (\tan 14^\circ) = 349
\]

For weight of pile per foot of height use \(W = 22 \text{ kips}\).

\[
TS = [122(17.4) + 349] (\tan 14^\circ) = 184
\]

4) **Apply Force at** \(\frac{2}{3} D\) **and Sum Moments About Tie Rod:**

\[
TS (H = \frac{2}{3} D - a_3) = 184(13.7) = 2470
\]

\[
(12,930 - 2470) + 33600 - 713 D^2 - 881 D^3 = 0
\]

\[
12,930 + 33600 - 713 D^2 - 881 D^3 = 0
\]

\[D = 5.3\], use \(D = 5.5\)

5) **Find Tie Rod Using Unfactored Soil Parameter by Summing Moments of Resultant Forces About \(\frac{2}{3} D\):** (Eq. 4-3)

\[
\frac{1}{2} K a_3 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) + \frac{1}{2} K a_2 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) + \frac{1}{2} K a_3 Y_3 \frac{4}{3} (\frac{4}{3} a_2 + a_3) + K a_2 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) + K a_3 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4)
\]

\[
K a_3 Y_3 \frac{2}{3} (\frac{2}{3} a_3 - a_4) - P (H = \frac{2}{3} D - a_3) = 0
\]

\[
2760 + 910 + 2280 - 1140 = 13.7 P
\]

\[P = 983 \text{ kips}\]
6) FIND POINT OF ZERO SHEAR

\[ P = \frac{F(T - \frac{1}{2} K_2 Y_2 x^2 - K_2 x) x = 0}{2a} \]

where
- \( a = \frac{2K_2 Y_2}{2a} = 7.68 \)
- \( b = K_2 Y_2 x \) (4.4, 460)
- \( c = 1 - \frac{1}{2} K_2 Y_2 x^2 - P \times e = 740 \)

\[ x = 2.72' \text{ below the water line} \( (Z_1) \) \]

7) FIND MAXIMUM MOMENT

\[ M_{max} = \beta (\frac{1}{2} x - n_4) - F(T - \frac{1}{2} K_2 Y_2 x^2 - K_2 x) \]

\[ = (568)(2.72') - (223)(8.05) - (777) - (7340) \]

\[ = 2690 \text{ ft.-lb} \]

8) COMPUTE TIE-ROD LOAD BASED UPON ROWE METHOD:

\[ \alpha = \frac{H_0}{12} = 1.44 \]  
\[ \beta = \frac{H_0^2}{D_3} = 6.3 \]  
\[ \gamma = 1.02 \]  

(FIG. 2.17b)

\[ P = \frac{F_e \cdot P_{req}}{1.02} \]  
\[ = (42)(903) = 1000 \text{ lb} \]

For spacing of ties at 7" centers

\[ T = p \times 7" = 7,900 \text{ lb} \]

9) COMPUTE BENDING MOMENT

\[ \theta = \frac{f_1 + \frac{1}{2} M_{max} H_0^3}{(2)(3690)(17.5)^3} = 8.26 \]  

(EQ. 4-8)

Using FIG. 2-176 for values of \( f_1 \): Interpolate 0.20 x distance between loose sand and dense sand \( f_1 = 0.7 \). Use of 20% for interpolation stems from choosing \( \gamma = 30' \) for loose sand, \( \beta = 40' \) for dense sand, and \( \beta = 52' \) for the subgrade so that:

\[ \frac{32-30}{40-30} = 20\% \]
\[ \tau = \frac{T}{w \times rd} \]  
(\text{Eq. 4.11})

\[ T_{\text{str}} = \frac{w}{(\text{Hoop}^2)^{\frac{1}{2}}} \]  
(\text{Eq. 4.12})

\[ \psi = \frac{2\sigma}{E} = \frac{2(2000)}{E_{\text{wood}}} = 0.309 \text{ (wood)} \]

\[ = 0.240 \text{ (approx. for A328 steel)} \]

\[ = 0.400 \text{ (approx. for A690 steel)} \]

<table>
<thead>
<tr>
<th>\text{load}</th>
<th>-3.00</th>
<th>-2.75</th>
<th>-2.50</th>
<th>-2.25</th>
<th>-2.00</th>
<th>-1.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{rd}</td>
<td>0.97</td>
<td>0.48</td>
<td>0.39</td>
<td>0.29</td>
<td>0.27</td>
<td>0.27</td>
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<tr>
<td>\text{td}</td>
<td>4.94</td>
<td>3.97</td>
<td>3.22</td>
<td>2.81</td>
<td>2.40</td>
<td>2.25</td>
</tr>
<tr>
<td>\text{Hoop}^2 \frac{1}{2}</td>
<td>38.5</td>
<td>24.2</td>
<td>17.9</td>
<td>12.2</td>
<td>8.00</td>
<td>3.85</td>
</tr>
<tr>
<td>\text{T}_{\text{str}} \text{ (wood)}</td>
<td>11.6</td>
<td>8.0</td>
<td>5.45</td>
<td>3.71</td>
<td>2.53</td>
<td>1.17</td>
</tr>
<tr>
<td>\text{T}_{\text{str}} \text{ (A328)}</td>
<td>10.0</td>
<td>4.81</td>
<td>4.49</td>
<td>3.17</td>
<td>2.16</td>
<td>1.60</td>
</tr>
<tr>
<td>\text{T}_{\text{str}} \text{ (A690)}</td>
<td>19.4</td>
<td>7.16</td>
<td>6.88</td>
<td>3.82</td>
<td>2.76</td>
<td>1.54</td>
</tr>
</tbody>
</table>

(See plot next page)

3) Design Section

\[ M = T \cdot d A^3 \]  
(\text{Eq. 4.13})

\[ s = \frac{M}{\frac{d A^3}{2}} \]  
(\text{Eq. 4.16})

<table>
<thead>
<tr>
<th>\text{Material}</th>
<th>T</th>
<th>\text{M (in-lb)}</th>
<th>\text{T (ksi)}</th>
<th>s (\text{in}^3/\text{ft})</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{wood}</td>
<td>23.7</td>
<td>12,700</td>
<td>2,000</td>
<td>0.349</td>
</tr>
<tr>
<td>A328</td>
<td>246</td>
<td>13,300</td>
<td>25,000</td>
<td>0.932</td>
</tr>
<tr>
<td>A690</td>
<td>222</td>
<td>11,900</td>
<td>32,000</td>
<td>0.372</td>
</tr>
</tbody>
</table>

For wood section:

\[ s = \frac{1}{6} b t^2, \quad a = 12, \quad t = \sqrt{\frac{3}{2}} \]  
(\text{Eq. 5.10a})

\[ a = 1.78, \text{ use } 3 \times 12 \text{ (nominal size)} \]

For A328 & A690 steel, the smallest section, A328 has

\[ s = 1.9 \text{ in}^3/\text{ft} > s_{\text{req}} \]  
(TABLE 5-2)
c) **Recompute Flexibility Characteristics:**

\[
\Psi = \frac{f}{2EI} = \frac{S}{2EI} \quad \text{(Eq. 4.13)}
\]

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>E (psi)</th>
<th>S (in^3/in^2)</th>
<th>I (in^3/in^2)</th>
<th>\Psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>A328</td>
<td>25,000</td>
<td>30 x 10^6</td>
<td>1.9</td>
<td>2.6</td>
</tr>
<tr>
<td>A690</td>
<td>32,000</td>
<td>30 x 10^6</td>
<td>1.9</td>
<td>2.6</td>
</tr>
</tbody>
</table>

d) **Recompute Tstr and find intersection of the operating and new structural curves for A328 and A690 steel:**

<table>
<thead>
<tr>
<th>(\log p)</th>
<th>-2.25</th>
<th>-2.00</th>
<th>-1.75</th>
<th>-1.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T_{str}) A328</td>
<td>12.2</td>
<td>6.30</td>
<td>3.67</td>
<td>3.09</td>
</tr>
<tr>
<td>(T_{str}) A690</td>
<td>3.03</td>
<td>2.04</td>
<td>1.40</td>
<td>0.95</td>
</tr>
<tr>
<td>Top</td>
<td>4.69</td>
<td>4.69</td>
<td>3.16</td>
<td>2.19</td>
</tr>
<tr>
<td>Top</td>
<td>2.81</td>
<td>2.40</td>
<td>2.23</td>
<td>2.23</td>
</tr>
</tbody>
</table>

e) **Recomputed Values:**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>T</th>
<th>Minax</th>
<th>Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A328</td>
<td>2.66</td>
<td>4.300</td>
<td>0.572</td>
</tr>
<tr>
<td>A690</td>
<td>2.21</td>
<td>1.800</td>
<td>0.307</td>
</tr>
</tbody>
</table>

The sections selected are satisfactory. A cost analysis will determine which material is best: wood, A328 or A690.
Example 2: Using the conditions of Example 1, ascertain the desirability of a cantilevered wall.

1) Compute Depth of Penetration: Sum Moments about Toe

\[ \frac{1}{2} K_0 \gamma_1 e_1 \left( \frac{1}{3} t_1 + e_2 + 0 \right) + \frac{1}{2} K_0 \gamma_2 e_2 \left( \frac{1}{3} t_2 + 0 \right) + \frac{1}{2} \left( K_0 - K_3 \right) \gamma_3 D_3 = 0 \]

\[ \begin{align*}
321(9.33 - 0) & + 73(2.07 - 0) + 1220(4 - 0) + 1800 & - 29.40 & - 0 \nonumber \\
0 & = 15.4 & \nonumber 
\end{align*} \]

2) Neglect Toe Shear: Moment arm is \( \frac{3}{8} D \) and the resulting moment computed from toe shear is very small.

3) Find Maximum Moment:

a) Point of zero shear is some distance \( x \) below crease level (use unfactored soil parameters)

\[ F_1 + F_2 - F_R = K_0 \left( \gamma_1 e_1 + \gamma_2 e_2 \right) x - \frac{1}{2} \left( K_0 - K_3 \right) \gamma_3 x^2 = 0 \]

\[ (224 + 492 + 519) = 225x - 197x^2 \]

\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \], where \( a = 197, b = -225, c = -1935 \)

\[ x = 3.42 \]

b) \( M_{\text{max}} = F_1 \left( \frac{1}{2} e_1 + e_2 + x \right) + F_2 \left( \frac{1}{2} e_2 + x \right) + F_3 \left( \frac{1}{2} e_2 + x \right) \]

\[ + \frac{1}{2} K_0 \left( \gamma_1 e_1 - \gamma_2 e_2 \right) x^2 - \frac{1}{2} \left( K_0 - K_3 \right) \gamma_3 x^3 \]

\[ = (224)(12.9) + (492)(4.28) + (519)(7.61) \]

\[ + \frac{1}{2} (225)(3.42)^2 - \frac{1}{2} (394)(3.41)^3 \]

\[ = 10916 \text{ ft-lb} \]

4) Compute Bending Moment (wood only)

a) \( T_{\text{max}} = M_{\text{max}} \times 12 + wD^3 \)

\[ = \left( \frac{10916(12)}{15.4 + 12} \right)^3 \]

\[ = 3.00 \]
b) \( \alpha = \frac{H}{H_0} = \frac{(12)}{(15.4+12)} = \frac{(12)}{(27.4)} = 0.442 \)

c) Generate operating and structural curves. From Fig. 3.4, select values of \( H \) for the corresponding values of \( \log \beta \):

\[
\ \begin{align*}
T_p &= \beta \max \times \frac{1}{\rho_d} \\
T_{\max} &= \frac{1}{(H_0 \beta^2)^{1/3}}
\end{align*}
\]

For wood, \( \psi = \frac{2\beta}{E \nu} = \frac{(2)(1200)}{(15.4)(150)} \approx 0.035 \)

<table>
<thead>
<tr>
<th>( \log \beta )</th>
<th>-3.0</th>
<th>-2.75</th>
<th>-2.50</th>
<th>-2.25</th>
<th>-2.00</th>
<th>-1.75</th>
<th>-1.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho_d )</td>
<td>0.40</td>
<td>0.49</td>
<td>0.49</td>
<td>0.48</td>
<td>0.45</td>
<td>0.44</td>
<td>0.44</td>
</tr>
<tr>
<td>( T_p )</td>
<td>4.20</td>
<td>4.24</td>
<td>3.92</td>
<td>3.84</td>
<td>3.44</td>
<td>3.40</td>
<td>3.40</td>
</tr>
<tr>
<td>( (H_0 \beta^2)^{1/3} )</td>
<td>34.0</td>
<td>23.2</td>
<td>15.0</td>
<td>10.8</td>
<td>7.33</td>
<td>4.99</td>
<td>3.40</td>
</tr>
<tr>
<td>( T_{\max} )</td>
<td>10.4</td>
<td>7.07</td>
<td>4.82</td>
<td>3.26</td>
<td>2.24</td>
<td>1.32</td>
<td>1.04</td>
</tr>
</tbody>
</table>

It can be seen from inspection that the intersection of the graphs falls between \( \log \beta = -2.50 \) and \( \log \beta = -2.25 \). Approximating the structural and operating curve segments as straight and employing simple coordinate geometry yields:

\[
T = 3.87 \times 10 \log \beta = -2.35
\]

\[
M = T \times H_0 = (3.87)(15.4)^2 = 4342\text{ in} \cdot \text{lb}
\]

\[
S = \frac{M}{\beta} = \frac{43420}{2000} = 21.7\text{ in}^3
\]

\[
s = \frac{1}{2} \beta a^2, \text{ for } b \times 12\text{ in}, a = 3\text{ in}
\]

\[
t = 3.98\text{ in}
\]
9 x 12 (nominal) sheet-piles are required. This size section is probably not available, a steel section or navy wall would be appropriate.

For A328 steel:

\[ \psi = 0.260 \]

For wood:

\[ \psi = 0.305 \]

Forming a ratio of A328/wood and applying it against the existing values of \( T_{st} \) precludes generating another structural curve.

For \( \log p = -2.25 \), \( T_{st} = \left( \frac{0.260}{0.305} \right) (3.28) = 2.79 \)

For \( \log p = -2.50 \), \( T_{st} = \left( \frac{0.260}{0.305} \right) (4.82) = 4.10 \)

This segment of the curves is identified by:

\[
\begin{align*}
\log p & : -2.50 & -2.25 \\
T_{st} & : 3.92 & 3.84 \\
T_{op} & : 4.10 & 2.79 \\
\end{align*}
\]

\[
T = 3.91 \]

\[
M = (3.91)(25.4)^3 = 64,100 \text{ in-lb}.
\]

\[
\frac{M}{T} = \frac{(64,100)}{25,000} = 2.56 \text{ in}^3
\]
USE PMAZZ, WHERE $S = 5.4 \text{ m}^2$. NO RECOMPUTATION IS NEEDED AS THE SECTION MODULUS IS SUBSTANTIALLY GREATER THAN THE MINIMUM REQUIRED.

3) THE CANTILEVERED WALL IS MUCH LESS ECONOMICAL OWING TO THE GREAT INCREASES IN THE REQUIRED SECTION AND OVERALL PILE LENGTH.

EXAMPLE 3: USING CONDITIONS GIVEN IN EXAMPLE 1, FIND THE PENETRATION DEPTH, TIE-ROD LOAD AND BENDING MOMENT, USING THE DESIGN CHARTS:

1) COMPUTE $R_0$:

$$R = \frac{4.4^3 + 3.4^3}{1.8^3} = \frac{(40)^3 - (60)(8)^3}{(60)(12)^3}$$

$$= 0.358$$

$$c_0 = \left(\frac{H}{H_A}\right) \left(\frac{H_A}{H-H_A}\right) = \left(\frac{8}{12}\right) \left(\frac{2}{12-2}\right)$$

$$= 0.0689$$

$$R_0 = 2 \cdot c_0 = (0.358)(0.0689) = 0.0318$$

2) FIND $D'$: SINCE THE SUBGRADE IS SOMEWHERE BETWEEN THE "LOOSE" AND "MEDIUM" CONDITIONS, INTERPOLATION WILL GIVE THE DESIRED VALUES.

ENTER FIG. 4.4 $R_0 = 0.0318$ AND READ OFF $D'$ FOR "L/L" AND "L/M." INTERPOLATION BY CONSIDERING THE DESIRED VALUE TO BE 0.40 TIMES THE DISTANCE FROM "L/L" TO "L/M" GIVES THE PROPER VALUE.

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>$D'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/L DESIRED</td>
<td>$D' = \frac{2\pi}{4} \cdot \frac{0.303}{2} \cdot \left(\frac{0.303 - x}{x}\right) \cdot -0.147$</td>
</tr>
<tr>
<td>L/M</td>
<td>$D' = \frac{2\pi}{4} \cdot \frac{0.334}{2}$</td>
</tr>
</tbody>
</table>

$$X = 0.047$$

$$D' = 0.434 \rightarrow D = D' \cdot H = (0.434)(12) = 5.23\text{ ft}$$
3) **Compute RM1Pr**: 

$$RM = R_p = R \cdot CH \cdot R \cdot CD$$

$$CD = CM = \left( \frac{B}{H} \right) \left( \frac{HA}{W} \right) = \left( \frac{5.23}{12} \right) \left( \frac{2}{6} \right) = 0.109$$

$$RM = R \cdot CH = (0.358)(0.109) = 0.039 \neq R_p$$

4) **Find M'**: Interpolate by entering "L/L" and "L/M" @ $RM = 0.039$

<table>
<thead>
<tr>
<th>Condition</th>
<th>$3S$</th>
<th>$D'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/L</td>
<td>307</td>
<td>0.099</td>
</tr>
<tr>
<td>Desired</td>
<td>32</td>
<td>0.099-x*0.012</td>
</tr>
<tr>
<td>L/M</td>
<td>39</td>
<td>0.111</td>
</tr>
</tbody>
</table>

$$L = \frac{7}{3} = \frac{2}{3}H - HA = \left( \frac{2}{3} \right)(5.23) + 12 - 2$$

$$= 20.5'$$

$$M' = M\times L^3 = (0.103)(60)(13.5)^3$$

$$= 15,200 \text{ in} = (A328 STEEL)$$

5) **Find D'**: Enter "L/L" and "L/M" @ $R = 0.041$

<table>
<thead>
<tr>
<th>Condition</th>
<th>$3S$</th>
<th>$D'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/L</td>
<td>307</td>
<td>0.352</td>
</tr>
<tr>
<td>Desired</td>
<td>32</td>
<td>0.0352-x*0.0580</td>
</tr>
<tr>
<td>L/M</td>
<td>39</td>
<td>0.0982</td>
</tr>
</tbody>
</table>

$$x = \frac{0.058}{2} = 0.029$$

$$x = 0.0231$$

$$P = 0.0422$$

$$P = D' \times L^2 = (0.0422)(100)(13.5)^2 = 1130 \text{ ft lb}.$$
4. The percent difference between the results using the design charts with the results of the hand calculations are:

Penetration depth: -1.3%
Bending moment: 6.3%
Tie-rod pull: 18.0%

Example 4: Consider the site geometry of Example 1 and the following soil conditions and compute the penetration depth, bending moment and tie-rod pull:

\[
\begin{align*}
\theta_1 &= 30^\circ \\
\theta_2 &= 30^\circ \\
\theta_3 &= 0 \\
\alpha_1 &= 300\text{ psf}
\end{align*}
\]

1) Determine stability number and soil parameters:

\[
S_c = \frac{Cr}{(\gamma_{s1} - \gamma_{s2})} = \frac{(300)(1.25)}{(0.09)(4) - (21.5)(3)} = 0.435 > 0.25, \quad \text{OK}
\]

\[
\delta_1 = \delta_2 = 30^\circ, \quad \kappa_s = 0.279 \quad \text{(UNFACTORED)}
\]

\[
C = \frac{1}{\delta_2} = \frac{1}{(30^\circ)}(300) = 100\text{ psi}
\]

2) Compute resultant forces and sum moments about tie rod:

\[
\begin{align*}
\frac{1}{2}k_0y_1y_2(\frac{2}{3}t_2 + t_3 - H_a) &= \frac{1}{2}k_0y_2^2(\frac{2}{3}t_2 + t_3 - H_a) = k_0y_2^2 \\
(\frac{1}{2}t_2 + t_3 - H_a - 4C^r - \gamma_1t_1 - \gamma_2)D &= (\frac{1}{2}t_2 + H - H_a) = 0
\end{align*}
\]

169 + 3770 + 9260 - (139.2)D (\frac{1}{2}C + 8) = 0

29.6 D^2 + 1114 D - 9280 = 0

\[
D = \frac{-1114 \pm \sqrt{1114^2 - 4 \cdot 29.6 \cdot (-9280)}}{2 \times 29.6}
\]

Where \( D = 69.6 \), \( \gamma = 1114 \), \( C = 9280 \)

\( D = 4.02 \)
3) FIND THE PROD LOAD BY SUMMING MOMENTS ABOUT $\frac{1}{2} D$:

$$\frac{1}{2} k_a x_1 x_2 \left( \frac{1}{3} t_1 + t_2 - \frac{1}{2} D \right) - \frac{1}{2} k_a y_2 x_2 \left( \frac{1}{3} t_2 + \frac{1}{2} D \right) +$$

$$k_a y_1 t_1 x_2 \left( \frac{1}{2} - \frac{1}{2} D \right) = P \left( \frac{1}{2} D + H + H_a \right) = 0$$

$2750 + 2910 - 6250 - P (13) = 0$

$P = 910 \ Y/Fa$

4) FIND THE POINT OF ZERO SHEAR

$P = F_1 - \frac{1}{2} k_a y_2 x_1^2 - k_a y_1 t_1 x_0 = 0$

$910 - 223 - 8.04 x_1^2 - 112 x_1 = 0$

$$x_1 = -\frac{b + \sqrt{b^2 - 4ac}}{2a}$$

WHERE $a = 112$

$$b = 8.04$$

$$c = -(910 - 223) = -6 93$$

$$x_1 = 4.49$$

5) COMPUTE $M_{\text{max}}$

$$M_{\text{max}} = P_1 \left( t_1 + x_1 \right) = 2750 \left( \frac{1}{3} t_1 + t_2 \right) = \frac{1}{2} ax^3 - \frac{1}{2} ax^2$$

$= (910) / (4.49) = (223) (5.94) - (1.34) (4.49)^3 - (56) (4.49)^2$

$= 3412 \ Y/Fa$. $= 4/Fa$

6) COMPUTE BENDING MOMENT

a) $M_{\text{max}} = (12) M_{\text{max}} / Ho^3 = (12) (3412) / (18)^3$

$$a = \frac{11}{10} = \frac{12}{18} = 0.67$$

$= \frac{11}{10} = \frac{2}{18} = 0.11$
b.) GENERATE OPERATING AND STRUCTURAL CURVES:

\[ T_{op} = T_{max} \cdot \Pi \] (VALUES OF \( \Pi \) ARE FROM FIG. 3.3a)

\[ T_{op} = \frac{\Psi}{(40.8)^{\frac{1}{3}}} \]

- USE \( \Psi = 0.305 \) (Wood)
- \( \Psi = 0.260 \) (A328)
- \( \Psi = 0.400 \) (A690)

<table>
<thead>
<tr>
<th>( \log \Pi )</th>
<th>-3.1</th>
<th>-2.4</th>
<th>-2.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Pi )</td>
<td>0.79</td>
<td>0.76</td>
<td>0.71</td>
</tr>
<tr>
<td>( T_{op} )</td>
<td>4.95</td>
<td>5.33</td>
<td>4.98</td>
</tr>
<tr>
<td>( \Psi )</td>
<td>44.5</td>
<td>20.6</td>
<td>9.56</td>
</tr>
<tr>
<td>( T_{op} ) (Wood)</td>
<td>13.0</td>
<td>6.28</td>
<td>2.92</td>
</tr>
<tr>
<td>( T_{op} ) (A328)</td>
<td>11.6</td>
<td>5.36</td>
<td>2.49</td>
</tr>
<tr>
<td>( T_{op} ) (A690)</td>
<td>17.6</td>
<td>8.28</td>
<td>3.89</td>
</tr>
</tbody>
</table>

C.) RECOMPUTATION OF \( T_{op} \) IS NOT NECESSARY. INSPECTION OF THE GRAPH SUGGESTS THAT LITTLE CHANGE IN \( \Psi \) WILL RESULT.

d.) \( M = T \cdot \Pi \cdot \rho \)

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>( T )</th>
<th>( M(\text{m}^3/\text{ft}) )</th>
<th>( F_{\text{act}}(\text{psi}) )</th>
<th>( S(\text{in}^3/\text{ft}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>5.12</td>
<td>17,400</td>
<td>2,000</td>
<td>4.0</td>
</tr>
<tr>
<td>A328</td>
<td>5.16</td>
<td>30,000</td>
<td>25,000</td>
<td>1.19</td>
</tr>
<tr>
<td>A690</td>
<td>5.25</td>
<td>79,500</td>
<td>37,000</td>
<td>0.92</td>
</tr>
</tbody>
</table>

7.) SELECT MEMBER SIZE:

a.) Wood: \( t = \sqrt{\frac{M}{2}} = \sqrt{17,400} = 2.73 \) in.; USE 4x12 (Nominal)

b.) A328; USE 8x28; \( S = 1.9 > 1.19 \)

c.) A690; USE 8x28; \( S = 1.9 > 1.19 \)
8) **Tie-Rod Load**

a) From Fig. 3.36, values of $P_c$ for $E / \sigma = 0.435$ are:

<table>
<thead>
<tr>
<th>$\log_10 \sigma$</th>
<th>$1.0$</th>
<th>$1.03$</th>
<th>$1.05$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_c$</td>
<td>$1.40$</td>
<td>$1.39$</td>
<td>$1.38$</td>
</tr>
</tbody>
</table>

b) Values of $\log_10 \sigma$ can be established from

$$\rho = \frac{H^+}{E^2}$$

and $P_c$ can then be interpolated. The tie-rod load for spacing of 7'-6" is then computed by

$$T = (7.5) P_c P_{fl4}$$

<table>
<thead>
<tr>
<th>Material</th>
<th>$E (\text{ksi})$</th>
<th>$I (\text{in}^4 / P_c)$</th>
<th>$/ \sigma$</th>
<th>$P_c$</th>
<th>$P_{fl4}$</th>
<th>$T (\text{ft})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>$1.5 \times 10^6$</td>
<td>38.4</td>
<td>-2.74</td>
<td>1.29</td>
<td>9.1G</td>
<td>8340</td>
</tr>
<tr>
<td>A328</td>
<td>$20 \times 10^6$</td>
<td>2.6</td>
<td>-2.90</td>
<td>1.34</td>
<td>9.1G</td>
<td>9230</td>
</tr>
<tr>
<td>A490</td>
<td>$50 \times 10^6$</td>
<td>2.8</td>
<td>-2.90</td>
<td>1.34</td>
<td>9.1G</td>
<td>9230</td>
</tr>
</tbody>
</table>
EXAMPLE 5: USING THE CONDITIONS GIVEN IN EXAMPLE 3, FIND THE PENETRATION DEPTH, BENDING MOMENT AND TIE ROO PULL, USING THE DESIGN CHARTS.

1.) COMPUTE RO

\[ R = \frac{Y_1 \times 3 + Y_2 \times 2}{(50 \times Y_2 - Y_2 \times 2) H^2} = \frac{(100)(4)^3 + (57.4)(8)^3}{(150)(1200\times (12) - (57.4)(8)) = 0.390} \]

\[ C_0 = \frac{H_w}{(H - H_4) \times 6} = \frac{3}{(12-2)(0.435)} = 1.84 \]

\[ R_0 = R \times C_0 = (0.390)(1.84) = 0.717 \]

2.) COMPUTE D: ENTER FIGURE 4-7 \( R_0 = 0.717 \) AND READ OFF D' FOR \( C, \frac{H}{D} = 0.25 \):

\[ D' = 0.488 \]

\[ D = D'H = (0.488)(12) = 5.86' \]

3.) COMPUTE Rm (FIND M)

\[ C_m = 1 \]

\[ R_m = R \times C_m = 0.390 \]

ENTER FIGURE 4-9 \( R_m = 0.390 \) AND READ OFF M' FOR \( C, \frac{H}{M} = 0.25 \):

\[ M' = 2.99 = \frac{K}{C} \] \( (C = 25 \times 1515 \times 1 = 3) \)

\[ M = M' \times 2 \]

\[ M = (2.99)(300)(5.86)^2 = 30,800 \text{ lbs} \]
4) COMPUTE \( R_0 \) & FIND \( p \):

\[ C_0 = \left( \frac{4a}{D} \right)^3 = \left( \frac{2}{1.960} \right)^3 = 0.483 \]

\[ R_p = R \cdot C_0 = (0.390)(0.483) = 0.188 \]

ENTER FIGURE 4-B & \( R_p = 0.270 \) AND READ OFF \( \beta ' \) FOR:

\[ \frac{d}{2h} = 0.25 \]

\( \beta ' = 0.584 \)

\( \beta = \beta ' C_D = (0.584)(300)(5.86) = 974 \) kip.

5) COMPARING THE RESULTS WITH EXAMPLE 4:

DEPTH: -27% DIFFERENCE
SENDING MOMENT: 27% DIFFERENCE (4328 STEEL)
TIE-ROD PULL: -21% DIFFERENCE

THE SIGNIFICANCE OF THE TIE-ROD LOAD CAN BE EXAMINED BY COMPARING THE REQUIRED DIAMETERS.

DESIGN CHART VALUES:

\[ T = (974)(1.5) = 7309 \] kip

\[ A_{eq} = \frac{7309}{22,000} = 0.332 \text{ in}^2 \]

\[ d = \sqrt{\frac{4A_{eq}}{\pi}} = \left[ \frac{4(0.332)}{\pi} \right]^{\frac{1}{2}} = 0.69 \]

HAND CALCULATION:

\[ T = 9230 \] kip

\[ A_{eq} = \frac{9230}{22,000} = 0.420 \text{ in}^2 \]

\[ d = \left[ \frac{4(0.420)}{\pi} \right]^{\frac{1}{2}} = 0.73 \]
EXAMPLE G: ATTERBERG LIMIT TESTS PERFORMED ON THE CLAY FRACTION OF THE SUBGRADE MATERIAL IN EXAMPLE 9 REVEALED:

WATER CONTENT: W = 40%  
LIQUID LIMIT: LL = 55%  
PLASTIC LIMIT: PL = 34%

1) DETERMINE PLASTICITY INDEX (LIQUIDITY INDEX):

\[ PI = LL - PL = 55 - 34 = 21 \]

\[ IL = \frac{W - PL}{PI} = \frac{40 - 34}{21} = 0.29 \]

2) DETERMINE ACTIVITY (60% CLAY):

\[ A = \frac{PI}{% CLAY} = \frac{21}{60} = 0.35 \]

The indicators suggest that this clay soil will cause no troubles (low activity, low plasticity and low liquidity index.) See Wu, 1976

3) THE DRAINED STRENGTH CAN BE ESTIMATED AS:

\[ q = 26'' \]  
(Wu, 1976)

4) RECALCULATE PENETRATION DEPTH:

\[ r = \frac{x_i - x_e}{x_e} = \frac{(100)(4)^3 - (57.6)(8)^3}{(47.6)(12)^3} = 0.436 \]

\[ c_0 = \frac{(H_w - H_e)^2}{w} \cdot \frac{A}{4 - A} = \frac{(8)^2}{12} \cdot \frac{2}{12} = 0.0589 \]

\[ P_0 = r \cdot c_0 = (0.436)(0.0589) = 0.0388 \]

ENTER FIGURE 4-10 @ R0 = 0.0388 AND READ OFF D' FOR 'SANDFILL/PHI = 26''':

\[ D' = 0.719 \]

\[ D = D' \cdot H = (0.719)(12) = 8.62'' \]
7) Recalculate Bending Moment

\[ C_M = \left( \frac{D \times HA}{H \times HW} \right) = \left( \frac{(8.03)(3)}{12}(6) \right) = 0.179 \]

\[ R_M = R \times C_M = 0.436 \times 0.179 = 0.0780 \]

Enter Figure 4-12 @ RM = 0.0780 and read off M for "SAND FILL / PHC = 24"

\[ M = 0.100 \]

For \[ L = \frac{2}{3} \]

\[ = (\frac{2}{3})(8.43) + 10 = 15.73 \]

\[ M = M \times y_b L^3 = (0.098)(47.6)(15.8)^3 = 18,400 \text{ in-lb./ft.} \]

8) Recalculate Tie-Rod Pull:

\[ C_0 = C_M = 0.179 \]

\[ R_P = R \times C_0 \times R_M = 0.078 \]

Enter Figure 4-11 @ R_P = 0.0780 and read off P for "SANDFILL / PHC = 24"

\[ P = 0.0334 \]

\[ P = P \times y_b L^2 = (0.0334)(100)(15.8)^2 = 334 \text{ lb./ft.} \]
EXAMPLE 7: DETERMINE THE DIAMETER OF THE TIE-ROD BASED UPON THE LOAD GIVEN IN EXAMPLE 1:

1) GIVEN: \( T = 7,500 \text{ ft-lb} \)

2) \[ d = \sqrt{\frac{4T}{\pi F_e}} \tag{Eq. 5-17} \]

   a) CHOOSE \( LF = 1.2 \) \tag{Sec. 5.2.4}

   b) \[ F_e = 0.60 F_u \]

   \[ = 0.60 \times (30,000) \text{ psi} \]

   \[ = 18,000 \text{ psi} \]

   \[ = 21,000 \text{ psi} \] \tag{Eq. 5-3}

   c) \[ d = \sqrt{\frac{4 \times (7,500)(1.2)}{\pi (21,000)}} \]

   \[ = 0.728 \text{ in.} \]

3) ADD \( \frac{1}{8} \text{ in.} \) FOR FRESH WATER \tag{728 5-9}

   \( d = 0.755 \text{ in.}, \) USE \( 7/8 \text{ in.} \)

   ADD \( \frac{1}{4} \text{ in.} \) FOR SALT WATER

   \( d = 0.778 \text{ in.}, \) USE \( 1 \text{ in.} \)

4) USE A 7/8 in. HOLE FOR THE TIE-ROD BEARING PLATE.

   A 1/32 inch hole for the wale and pile (wood wales).

   USE A 1/8 hole for the tie-rod passing through steel sheet piles.
EXAMPLE 8: GIVEN THE LOADS IN EXAMPLE #1, DESIGN A WALE FOR STEEL AND WOOD SHEET PILES.

1) GIVEN: \( P = 1000 \text{ } \#/	ext{A}., \ L = 7.5 \text{ } \text{A}.

2) DETERMINE MOMENT AND SECTION MODULUS REQUIRED

\[ M = \frac{1}{3} P L^2 \]
\[ = \frac{1}{3} \times 1000 \times (7.5)^2 \]
\[ = 75,000 \text{ in.}^2 \text{ lb.} \]

\( S = \frac{M}{F_0} \)

\[ = \frac{75,000}{22,000} \]

(a36 steel)

\[ = 3.41 \text{ in}^3 \text{, use 2 ea. } 4\times 9.4 \text{ channels} \]

\( s = \frac{1.93 \text{ in}^3}{\text{per channel} \times 2 \text{ channels}} \)

\[ = 1.93 \text{ in}^3 \times 2 \]

\[ = 3.86 \text{ in}^3 > 3.41 \text{ in}^3 \]

3) \( s = \frac{M}{F_0} = \frac{75000}{2000} \)

\[ = 37.5 \text{ in}^3 \]

4) USE 4\times 10 MEMBER, \( s = 54.53 \text{ in}^3 \)

(a36 steel, adequate section modulus, however a 1/32 in. hole leaves only 3.8 in. of wood between bolt and edge of wale.)
EXAMPLE #9: DETERMINE THE SIZE AND NUMBER OF NAILS REQUIRED TO FASTEN THE PILES DESIGNED IN EXAMPLE #1 TO

1) GIVEN:
   \( P = 1000 \) ft
   \( t = 2\frac{7}{8} \) in. (3 x 12 nominal)
   TIMBER MATERIAL IS SOUTHERN PINE

2) FIND G:
   \( G = 0.99 \) (Tab 3-6)

3) TRY A 40 PENNY NAIL (40A)

   \( L = 3 \) in.
   \( P = 83 \) ft/in.
   \( \Delta = 3\text{ in.} - 2\frac{3}{8} \text{ in.} = 2\frac{3}{8} \text{ in.} \)

   \( \Delta P = \Delta \times \Delta \times P \)
   \( = (0.25)(2.375) \)
   \( = 1.97 \) ft

4) NUMBER OF NAILS

   \( n = \frac{P}{\Delta P} \) (Eq. 5-19)
   \( = \frac{1000}{0.97} \)
   \( = 1032 \), USE 1032 NAILS/PILE

5) TRY A 40A SPIKE

   \( L = 3 \) in.
   \( P = 97 \) ft/in.

   \( \Delta P = \Delta \times \Delta \times P \)
   \( = 5 \times 2.375 \text{ ft} \)
   \( = 23.0 \) ft

   \( n = \frac{P \times \Delta}{\Delta P} \)
   \( = \frac{1000}{23} = 43.0 \), USE 4 SPIKES/PILE
**EXAMPLE 10:** DETERMINE THE NAIL SIZE REQUIRED TO FASTEN SHEET PILES TO AN OUTSIDE WADE.

1) GIVEN: \( t = 2 \frac{3}{8} \) in.

2) \( \ell = \frac{9}{33} \) 
   \[ = \left( \frac{3}{8} \right) (2.025) \]  
   = 4.375 in. \( \text{(Eq. 5-20b)} \)

3) USE 30 & NAIL (\( \ell = 4\frac{1}{2} \) in.) \( \text{(Tab 3-7)} \)

---

**EXAMPLE 11:** DESIGN A BEARING PLATE FOR THE TIE-ROD DESIGNED IN EXAMPLE 7.

1) GIVEN: \( T = 7500 \) ft
   \( d = 1 \) in. (1/8 in. hole)

2) DETERMINE AREA REQUIRED
   \[ A = \frac{T}{d} \]  
   \[ = \frac{7500}{1/8} \]  
   = 60,000 in. \(^2 \) \( \text{(Eq. 5-21)} \)

3) SIZE THE PLATE
   \[ A = bh \]  
   \[ = (3/2)(1.25)^2 \]  
   = 0.99 in. \(^2 \)  
   \[ h = \frac{(1.25)(1.25)}{3.5} \]  
   = 0.99, USE 3/2 x 9 in. PLATE

4) DETERMINE \( F_d, N \) AND \( \theta \)
   \[ F_d = \frac{T}{(A_d - A \text{-hole})} \]  
   \[ = \frac{7500}{[(3.5)(3) - (0.99)]} \]  
   = 454.35

   \[ N = \frac{1}{2} (d - A \text{-hole}) \]  
   \[ = \frac{1}{2} (3.5 - 1.25) \]  
   = 1.19

   \[ \theta = \sqrt{\frac{3 F_d N^2}{F_d^2}} \]  
   \[ = \sqrt{\frac{3(454.35)(1.19)^2}{454.35}} \]  
   = 0.30

   USE 2, 3/2 x 3.5 x 3
EXAMPLE #12: A UNIFORMLY DISTRIBUTED SURCHARGE LOAD OF 200 lb. PER SQ. FT. IS TO BE PLACED UPON THE BACKFILL OF THE SITE DESCRIBED IN EXAMPLE #1. DETERMINE THE REQUIRED PENETRATION DEPTH, TIE-ROD LOAD, AND MAXIMUM BENDING MOMENT.

1) GIVEN:  \( q_1 = 200 \text{ lb/ft}^2 \)
   GEOMETRY AND SOIL CONDITIONS GIVEN IN EX. #1

2) THE EFFECT OF THE UNIFORMLY DISTRIBUTED SURCHARGE IS A RECTANGULAR STRESS DISTRIBUTION IN EACH SOIL LAYER, AS SHOWN IN FIG. 4-2. COMPUTE THE RESULTING MOMENTS ABOUT THE TIE-ROD AND ADD TO THE MOMENTS COMPUTED IN EXAMPLE #1.

\[
egin{align*}
(K_{d1} g e_1) (\frac{1}{2} e_1 - H_1) &+ (K_{d2} q e_2) (\frac{1}{2} e_2 - e_1 - H_1) - (K_{d3} g d_3) \left( \frac{1}{2} d_3 - e_2 - H_3 \right) + (10,400 - 3,360 D - 713 D^2 - 58.8 D^3) = 0 \\
(10,400) + (28.2 D^2 - 764 D) - (30,400 - 3360 D - 713 D^2 - 58.8 D^3) = 0 \\
1,070 + 4120 D - 676 D^2 - 58.8 D^3 = 0 \\
\text{Solve:} \quad D = 0.2 \text{ ft}
\end{align*}
\]

3) SUM MOMENTS ABOUT \( \frac{1}{3} D \) TO DETERMINE TIE-ROD LOAD

\[
egin{align*}
(K_{d1} g e_1) (\frac{1}{2} e_1 - \frac{1}{3} D) - (K_{d2} q e_2) (\frac{1}{3} e_2 - \frac{1}{3} D) + \left(\frac{1}{2} K_{d3} g d_3\right) \left(\frac{1}{3} d_3 - \frac{1}{3} D - H_3\right) &+ (3150 - 3010 + 8990 + 3360 - 1770 - 141 D) = 0 \\
\text{Solve:} \quad D = 1810 \text{ lb/ft}
\end{align*}
\]

4) FIND POINT OF ZERO SHEAR, \( x \) FT BELOW THE WATER LEVEL (\( e_1 \)):

\[
\begin{align*}
\frac{-7.48 x^2 - 154 x - 1175}{2} &= 0 \\
x &= \frac{-b + \sqrt{b^2 - 4ac}}{2a} \\
x &= 9.3 \text{ ft below } e_1
\]

\[\text{where} \quad a = 7.48 \quad b = 154 \quad c = 1175\]
5) FIND MAXIMUM MOMENT

\[ M_{\text{max}} = \frac{3}{2} \left( \frac{9}{4} + \frac{x - H_a}{2} \right) - \frac{1}{2} k_0 x_1 c_1^2 \left( \frac{3}{4} + \frac{x}{12} \right) - k_0 q_1 \left( \frac{3}{4} + \frac{x}{12} \right) - \frac{1}{2} k_0 x_2 c_2^2 \frac{x}{12} - \frac{1}{2} k_0 x_2 \frac{x}{12} \times x^2 \]

\[ = 11,930 - 1610 - 440 - 2470 - 530 \]

\[ = 6480 \text{ ft.-lb.} = 6480 \text{ lb-ft.} \]

6) COMPUTE \( x/3 \):

\[ x = \frac{4}{3} \frac{H}{H_a} = \frac{12}{12+6.2} \approx 0.69 \]

\[ \frac{H}{H_a} = \frac{2}{12} = 0.17 \]

7) THE ROOF LOAD:

\[ F_c = 0.95 \]

\[ P = (0.95) \times 10 = 9.5 \text{ kips} \]

8) COMPUTE REDUCTIONS FROM OPERATING AND STRUCTURAL CURVES FOR WOOD, AS IN EX. #1:

\[ T_{\text{max}} = \frac{(12)(6400)}{(18.2)^2} = 13.3 \text{ kips} \]

\[ T = 4.56 \text{ kips} \]

\[ M = \frac{T}{g} \frac{L}{3} = (2.95)(18.2)^3 \]

\[ = 27,910 \text{ in.-ft.} \]

---

EXAMPLE 13: USE THE SIMPLIFIED METHOD FROM THE PRECEDING SITUATION

1) DETERMINE THE EQUIVALENT HEIGHT OF SOIL FOR \( q_1 \) AND ADD THIS TO THE FREE-StANDING WALL HEIGHT, \( H \):

\[ H_{eq} = \frac{q_1}{k_0} \frac{100}{100} = 2 \text{ ft.} \]

\[ h = 12 + 2 = 14 \text{ ft.} \]

2) FROM EX. #3, \( \frac{M}{H} = 0.436 = D' \)

\[ \Delta = D' \frac{H}{D' \frac{H}{D' \frac{H}} = (0.436) \times 14 = 6.1 \text{ ft.} \]

3) FROM EX. #3, \( M' = \frac{H}{8} \frac{L}{3} = 0.103 \)

\[ L = \frac{3}{2} D' + H - H_A = \left( \frac{3}{2} \times 6.1 \right) - 14 - (2) = 16.1 \text{ ft.} \]

\[ M = M' \frac{L}{3} = (0.103)(60)(14.1)^2 = 29800 \text{ in.-ft.} \]

4) FROM EX. #3, \( P' = \frac{D}{L} \frac{L}{2} = 0.0422 \)

\[ P = P' \frac{L}{3} = \left( 0.0422 \right) (100)(14.1)^2 = 1612 \text{ lb.} \]
Example 14: Determine the penetration depth, bending moment, and tie-rodd load for the wall in the previous example, instead of a point load, consider a continuous foundation footing 10 ft. from the sheet piles with a load of 5 kips/ft.

1) Given: \( c_1 = 5000 \) kips/ft.
\( x = 10 \) ft.
Geometry and soil conditions remain unchanged.

2) \( M = \frac{x}{H} = \frac{10}{1.12} = 0.83 \)

\[ P_h = \frac{0.64Q_d}{(M^2 - 1)} = \frac{(0.64)(5000)}{(0.83)^2 - 1} = 1890 \text{ kips/ft.} \quad (\text{Fig. 5-16}) \]

3) Extrapolate \( L \) from Figure 5-16. For \( M = 0.83 \), \( L = 0.43H = 3.16 \) ft.

4) Sum moments about tie-rodd, as in previous example:

\[ P_h(l - l_h) = (1990)(12 - 5.16 - 2) = 9150 \]

\( 9150 - (10400) = 3250 - 7130 \cdot 2 - 58.8 \cdot 3^3 = 0 \]

\( D = 6.2 \)

5) Sum moments about \( \frac{3}{4} \) D. Ph acts @ (L - \( \frac{3}{4} \) D) from \( \frac{3}{4} \) D:

\[ P_h(l - \frac{3}{4} D) = (1990) \left[ 12 + \left( \frac{3}{4} \right)(42) \right] = 17,960 \]

\( 17,960 - (3000 - 3340 - 1440) = 1412 \text{ kips/ft.} \)

6) Find point of zero shear:

\( c = \frac{1}{2} \cdot \frac{3}{8} \cdot x \cdot 12 - P_h - P = 313 \)
The value of C is positive, which indicates that the shear force diagram changes abruptly (at the point of PH) from positive to negative. This is where the maximum moment will occur.

\[ x = W - L - 5, = 2.84' \text{ below the water level.} \]

7) **Find \( M_{\text{max}} \)**

\[ M_{\text{max}} = (1800)(4.84) - (223)(4.17) - (60) - (413) = 7310 \text{ ft}^3/\text{ft}. \]

8) **Compute the tie-rodd load**

\[ \theta = \frac{1}{2} \beta_2 = 0.11 \quad \alpha = \frac{3}{2} \beta_2 = 0.66, \quad A_e = 0.95 \quad (\text{Fig. 2-17b}) \]

\[ P = 0.5 \times (24) (1800) = 1710 \text{ kips}. \]

9) **Compute bending moment reductions**

\[ T_{\text{max}} = (\alpha)(7310) / (18.2)^3 = 14.6 \]

Generating new \( T_{\text{m}} \) values using the same reduction factors will give

\[ T = 5.90 \]

\[ M = T \cdot H_0 = (5.90)(18.2)^3 = 35,500 \text{ kips ft}. \]
EXAMPLE 4.15: USE THE SIMPLIFIED METHOD FROM THE PRECEDING SITUATION.

1) DETERMINE AN EQUIVALENT HEIGHT OF SOIL FOR pH AND ADD THIS TO THE FREE STANDING WALL HEIGHT, H:

\[ H_{eq} = \frac{pH}{\gamma_s (H - L)} = \frac{1890}{(100)(12 - 5.14)} = 2.77' \]

\[ L = \frac{12 + 2.77}{14.8} = 14.8 \]

2) FROM EX. 4.3, \( \frac{D}{H} = 0.434 = \frac{D'}{H'} \)

\[ \therefore D = D' H = (0.434)(14.8) = 6.3' \]

3) FROM EX. 4.3, \( M' = \frac{M}{\gamma_s L} = 0.103 \)

\[ L = \frac{2.3 D - H - HA}{\gamma_s} = \frac{2.3(6.3) - (14.8) - (2)}{17.13} = 17.13' \]

\[ M = M' \gamma_s L^3 = (0.103)(0.2) (17.13)^3 = 31,100 \text{ in.}^3/\text{ft}^3 \]

4) FROM EX. 4.3, \( \frac{P'}{\gamma_s L^2} = 0.0622 \)

\[ P = P' \gamma_s L^2 = (0.0622)(100)(17.1)^2 = 1820 \text{ lb/ft}^2 \]
Example 16: A 10,000 lb load is to be located 5 ft. from the sheet piles of the wall given in Ex. #1. Determine the required penetration depth, the rod load, and maximum bending moment.

1) Given: \( q_0 = 10,000 \) \( \text{lb} \)
   \( x = 5 \) \( \text{ft} \)
   Geometry and soil conditions given in Ex. #1

2) \( m = \frac{x}{H} = \frac{3}{15} = 0.2 \)
   \( P_h = 0.45 \frac{q_0}{H} = 0.90 \text{ lb/ft} \)

3) Interpolate \( L \) from Fig. 9-16
   \( L = 0.5H = 0.48 \text{ ft.} \)

4) Sum moments about the rod:
   - \( P_h \) acts at 5.4 ft. from DL or \( (H-L-HA) = 3.52 \text{ ft.} \) from the rod.
   - Add \( P_h (H-L-HA) \) to moments computed in step 4, Ex. #1:
     \( (450)(3.52) + 10400 - 33600 - 7130^2 = 5680^3 = 0 \)
     \( D = 5.5 \text{ ft.} \)

5) Sum moments about \( \frac{L}{2} \), \( P_h \) acts at a distance \( (L-\frac{L}{2}) = 15.7 \text{ ft. from } \frac{L}{2} \)
   - Add \( P_h (L-\frac{L}{2}) \) to moments computed in step 5, Ex. #1:
     \( (450)(15.7) - (2900 + 3110 - 4280 + 1140) = 137 \text{ ft} \)
     \( D = 1500 \text{ ft.} \)

6) Find point of zero shear as in step 6, Ex. #1, except that:
   \( c = \frac{1}{2} k_0 \sqrt{x} \frac{q_0}{x} + P_h - P = 0.23 \)
   \( x = 7.10 \text{ ft. below the water level} \) (i.e., below \( L \) )
7) FIND THE MAXIMUM MOMENT, AS IN STEP 7, EX. #1 INCLUCING THE MOMENT CAUSED BY PH (L+2, X = H)

\[ M_{\text{max}} = -(450)(6.48 - 4 + 7.10 - 12) + (1500)(9.10) - (223)(8.49) - (910) - (2580) \]
\[ = 5740 \text{ ft. \#/ ft.} \]

2) COMPUTE THE TIE-ROD LOAD, AS IN STEP 3, EX. #1:

\[ \beta = 2/17.5 = 0.11, \alpha = 12/17.5 = 0.69, \frac{P_0}{P_2} = 1.0 \quad \text{FIG 2-17b} \]

\[ P = \frac{P_0}{P_2}P_{\text{tas}} = (1.0)(1500) = 1500 \text{ \#/ ft.} \]

9) COMPUTE BENDING MOMENT REDUCTION AS IN STEP 9, EX. #1:

\[ P_{\text{max}} = (12)(5740)/(17.5)^3 = 12.90 \]

GENERATE NEW \( P_0 \) VALUES USING THE SAME REDUCTION FACTORS AS IN EX. #1.

\[ P = 3.48 \]

\[ m = \frac{P}{H}^3 = (3.48)(17.5)^3 = 18,450 \text{ \#/ ft.} \]

EXAMPLE #17: USE THE SIMPLIFIED METHOD FOR THE PRECEDING SITUATION.

1. DETERMINE AN EQUIVALENT HEIGHT OF SOIL FOR PH AND ADD THIS TO THE FREE STANDING WALL HEIGHT, H:

\[ H_{eq} = \frac{PH}{\frac{P_0}{P_2}P_{\text{tas}}} = \frac{450}{(100)(1.2-0.48)} = 0.32 \]

\[ L = 12 - 0.32 = 12.68 \]

2) FROM EX. #3, \( D = 0.436 \times D' \)

\[ D = D' + H_{eq} = (0.436)(12.62) = 5.59 = 3.6' \]

3) FROM EX. #3, \( M' = \frac{M}{H_{eq}^3} = 0.103 \)

\[ L = \frac{3}{2}D + H_{eq} = \frac{3}{2}(5.6) + (12.62) - (2) = 14.5 \]

\[ M = M' \frac{L^3}{3} = (0.103)(60)(14.5)^3 = 19,600 \text{ in.} \]

4) FROM EX. #3, \( P' = \frac{P}{H_{eq}^2} = 0.0422 \)

\[ P = P' \frac{L^2}{3} = (0.0422)(100)(14.5)^2 = 350 \text{ \#/ ft.} \]
EXAMPLE 12: DESIGN A 2 MEMBER SPlice FOR AN INCLINE WALE HAVING THE DIMENSIONS AND LOADS AS IN EXAMPLE # 6.

1) GIVEN: WALE IS 4 X 10
   M = 75000IN.-FT.

2) SELECT Lb, FIND V
   TRY Lb = 24 in.

   \[ V = \frac{1}{2} - \frac{31b}{4} \]
   \[ = \left( \frac{75000}{2} \right) - \left( \frac{1000}{4} \right) \left( \frac{24}{12} \right) \]
   \[ = 3250 \text{ ft} \text{lb} \]

3) USE THE SAME SIZE MEMBER AS THE WALE FOR THE SPICE PLATE, SELECT d AND \( a \) BASED ON \( b \)
   FOR 4 X 10, \( b = 3 \frac{7}{8} \) in.
   \( d = 1 \text{in.} \) 
   \( a = 10 \text{in.} \)

4) NUMBER OF BOLTS REQUIRED 3 EACH END
   \[ n = \frac{3250}{310} = 4.01 \] USE 2 ROWS OF 2 BOLTS

5) DETERMINE DISTANCE REQUIREMENTS FOR BOLT DIAMETER OF 1 in. (\( \frac{3}{8} = 3.49 \text{ in.} = 3.425 \text{ in.} \))
   EDGE = 4 in.
   BOLT SPACING = 4 in.
   END = 1 \( \frac{1}{2} \) in.
   ROW SPACING = 3.5 in.

6) THE DISTANCE REQUIREMENTS FOR EDGE AND ROWS OF BOLTS EXCEED THE DIMENSION OF THE MEMBER. REPEAT STEPS 2 THROUGH 3, USING 4 X 1\( \frac{1}{2} \) INCHES. THIS WILL PERMIT OVERALL LENGTH OF THE SPICE PLATE OF 74 IN. ALLOWING END DISTANCES OF 1\( \frac{1}{2} \) IN. @ EACH END.
7) \( V = \left( \frac{7500}{2} \right) = \left( \frac{100}{2} \cdot \frac{21}{12} \right) = 3312 \)

For \( \frac{3}{8} \) in bolt, \( Q = \frac{140}{2} = 70 \) psi.

\( n = 3312 \times 0.438 \) :: Use 2 rows of 3 bolts.

For a \( \frac{5}{8} \) in bolt, \( \lambda / \alpha = 5.8 \)

\( S_{oa} = 2.3 '' \) :: Bolt spacing = 2.3 ''

\( S_{eo} = 0.938 \) :: End 1''

Row spacing: \( \frac{s}{\lambda} = 3.025 / 0.625 = 5.4 \)

\( n_2 = (\frac{9}{8}) \times 5.8 \cdot 1/4 = 4.275 \)

Row spacing: \( (4.275) / (9/8) = 3.05 \), say 3 in.

b) Use 6 each \( \frac{3}{8} \) in bolts in each end.
EXAMPLE 19: DESIGN A 3 MEMBER SPICE USING THE DATA FROM THE PREVIOUS EXAMPLE.

1) GIVEN: WALE IS 4 x 10  
   M = 75000 IN-LB

2) USE SAME L3 AS PREVIOUS EXAMPLE  
   FOR L3 = 21 IN., v = 33/12

3) SELECT A SPICE DIMENSIONS:  
   THE SECTION OF EACH PLATE MUST BE 1/2 THE REQUIRED.  
   REQUIRED S = 37.5 IN²; 2.5 = 18.75  
   USE 2 x 10 (S = 24.44 > 18.75) (TAB 5-46)  
   a = 1.025 (FIG. 5-11)
   TAKE b = 2a = (2)(1.025) = 3.25
   USE x = b = 3.0 IN TABLE 5-6

4) SELECT z AND g  
   FOR 5/8 IN. BOLT, Q = 1000
   \[ \frac{3.312}{1000} = 3.31 \rightarrow \text{USE 2 ROWS OF 2 BOLTS} \]

5) DETERMINE SPACING FOR \( \frac{z}{a} = \frac{3.31}{1.025} = 3.25 \)
   EDGE = 2.5  
   END = 0.338  
   BOLT SPACING = 2.5  
   ROW SPACING = (2.5 + 2) = 2.5

6) USE 4 EA. 3/8 IN. BOLTS AT EACH END

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EXAMPLE 92C: DETERMINE THE FASTENERS REQUIRED FOR THE STEEL SHEET PILE WALL IN EXAMPLE 91 AND THE WALES IN EXAMPLE 98.

1) GIVEN: P52B SECTION
   C3x5 WALES
   P = 1000 P/FT.

2) DETERMINE THE NUMBER OF BOLTS REQUIRED FOR AN INSIDE WALE.
   USE W = 13 IN.
   SELECT A 5/8 IN. BOLT (SMALLEST BOLT) (TAB 5-2)

   T = \frac{4P\omega}{\pi d^2 f_c}
       \frac{(4)(1000)(13)}{(0.625)^2(40,000)}
       \approx 0.102

   USE 1 BOLT EVERY OTHER SECTION

3) DIMENSION THE FIXING PLATE
   USING PIPE SEPARATORS 2 IN. LONG GIVES A SPAN BETWEEN CHANNELS OF 2 IN.
   USING 1 EA. 5/8 IN. BOLT EVERY OTHER SECTION EXERTS A TENSILE FORCE IN THE BOLT OF

   F = 2P\omega = (2)(1000)(13)
      = 2700 P

   THE MOMENT IN THE FIXING PLATE IS

   M = \frac{1}{2}PL = \frac{1}{2}(1500)(12)
      = 1250 IN.-LB.
\[ T = \sqrt{\frac{GM}{bF_b}} \]

For \( b = 3 \text{ in.} \)

\[ T = \sqrt{\frac{(6)(1250)}{(4)(22,000)}} = 0.29, \text{ use } T = \frac{3}{8} \text{ in.} \]

Edge distance = \( 1.25 \times (1.25)(\frac{5}{8}) = 0.78 \text{ in.} \)

Required minimum distance is twice the edge distance plus the bolt hole. The bolt hole is \( 3/8 \text{ in.} \) larger than the bolt.

\[ 2 = (2)(0.78) + (\frac{5}{8}) + (\frac{1}{2}) = 2.31 \text{ in. min.} \]

Use \( 3\frac{5}{8} \times 3 \times 3 \)

1) GIVEN: \( M = 75,000 \text{ in.-lb}, \hspace{1cm} 4 \times 5.4 \text{ CHANNELS} \)

2) PLATE WIDTH IS LIMITED BY THE FLANGE-TO-FLANGE WIDTH OF THE CHANNELS, EDGE DISTANCE AND BOLT HOLE DIAMETER.

\[ b = d - 2\delta \]

\[ = (2.00) - (2)(0.196) \]

\[ = 3.44 \text{ in.} \]

(TAB 5.3)

For a \( \frac{3}{8} \) in. bolt, the edge distance and bolt hole requirements give a minimum \( b \) of 2.31 in. (EX 9.1B)

\[ \therefore b = 3\frac{3}{8} \text{ in.} \]

3) \( s = \frac{m}{2b} = 3.41 \text{ in.}^3 \) (FROM EX 9.3) (EQ 9.9)

\[ s = \frac{1}{2} 46^2 \text{ in.}^3 \text{ (BENDING ABOUT STRONG AXIS) (EQ 9.10a)} \]

\[ t = \frac{46}{2} = 1.94 \text{ in. FOR 2 PLATES (TOP & BOTTOM CHANNELS)} \]

4) USE A 12 in. long plate, minimum edge distance is 1.903, or 0.94 in. for \( \frac{3}{8} \) in. bolts, use \( L_0 = 10 \text{ in.} \)

\[ V = \frac{T}{2} - \frac{PLb}{4} \]

\[ = \left( \frac{3500}{2} \right) - \left( \frac{1000}{4} \right) \left( \frac{12}{12} \right) \]

\[ = 3542 \text{ in.-lb} \]

(EQ 9.23)

5) CAPACITY OF A \( \frac{3}{8} \) BOLT IN SINGLE SHEAR IS

\[ F_v = (15,000)a : (13,000)(\frac{3}{8})^2 : 4600 \text{ in.-lb} \]

CAPACITY IN DOUBLE SHEAR IS 9200 in.-lb > 3542 in.-lb

\[ \therefore \] USE 1 EACH \( \frac{3}{8} \) in. BOLT @ 1 in. FROM THE END.

USE \( 2\frac{1}{2}'' 	imes 3'' 	imes 1/2'' (2 \text{ EACH}) \).
EXAMPLE 2.22: GIVEN THE CONDITIONS OF EXAMPLE 1, DESIGN A CONTINUOUS DEADMAN ANCHORAGE.

1) GIVEN: $h_a = 2 \text{ ft}$, $k_p' = 3.00$, $k_p = 300 \text{pcf}$, $k_a = 0.408$

2) SELECT $h_1 = 1 \text{ ft}$, $k_p' - k_a = 2.59$

3) LET $h_w = h_a$, ALTHOUGH THE TIE-ROD IS LOCATED SLIGHTLY ABOVE THE WATER LINE.

4) COMPUTE THE RESULTANT FORCES ACTING ON THE ANCHORAGE (FIGURE 5-25)

4a) NET FORCES:

\( (k_p' - k_a) y_1 h_w h_L = (2.59)(100)(1) h_L = 259 h_L \)

\( \frac{1}{2} (k_p' - k_a) y_1 (h_w - h_1)^2 = \frac{1}{2} (2.59)(100)(2.1)^2 = 129.5 \)

\( (k_p' - k_a) y_2 (h_w - h_1)(h_w + h_L - h_w) = (2.59)(100)(2.1)(h_L - 1) \)

\( = 259 h_L - 259 \)

\( \frac{1}{2} (k_p' - k_a) y_2 (h_w + h_L - h_w)^2 = \frac{1}{2} (2.59)(100)(h_L - 1)^2 \)

\( = 77.7 h_L^2 - 155.4 h_L + 77.7 \)

b) SUM NET FORCES, EQUATE TO TIE-ROD PULL/UNIT LENGTH.

\( P = 259 h_L + 129.5 + 259 h_L - 259 h_L + 77.7 h_L^2 - 155.4 h_L + 77.7 \)

\( 1000 = 77.7 h_L^2 + 358.6 h_L - 51.6 \)

c) SOLVE THE QUADRATIC FOR $h_L$

\( 77.7 h_L^2 + 358.6 h_L - 1051.8 = 0 \)

\( h_L = \frac{-358.6 \pm \sqrt{(358.6)^2 - 4(77.7)(-1051.8)}}{2(77.7)} \)

\( = 2.04, -6.55 \)

USE POSITIVE ROOT, $h_L = 2.04$; 2.00 IS OK.

5) USING THE SAME MATERIAL AS THE WALL REQUIRES NO FURTHER DESIGN. WALES ON THE ANCHORAGE ARE THE SAME AS FOR TIE-WALES ON THE WALL.

6) ENSURE THAT THE TOE OF THE WALL DOES NOT INTERSECT THE FAILURE WEDGE (FIGURE 5-6).
EXAMPLE #23: USING THE DATA OF EXAMPLE #15, DESIGN A SHORT DEADMAN.

1) GIVEN: \((P_o-P_r) = 77.7 \, \text{kN}^2 + 358.6 \, \text{kN} \cdot \text{m} = 51.8\)
   \(x_1 = 100\) \(K_o = 3.20\) \(\theta = 2^\circ\)
   \(x_2 = 50\) \(K_d = 0.408\) \(K_o = 0.4\)

2) SELECT A LENGTH: \(L = 4\, \text{ft}\).

3) INCORPORATE THE DATA OF EX. #15 INTO EQ. 5-7:

\[ T_{W} = L \, (P_o-P_r) - \frac{1}{2} \, K_o \left( \frac{K_o'}{K_o} + \frac{K_d'}{K_d} \right) \frac{h_1 \cdot \tan \theta}{h} \]

2 VALUES OF \(x, y\) OVER THE LENGTH \(h_2 - h_1\)

\[ T_{W} = \frac{1}{2} \, K_o \left( \frac{K_o'}{K_o} + \frac{K_d'}{K_d} \right) \frac{h_1 \cdot \tan \theta}{h} \]

\[ = (4)(77.7 \, \text{kN}^2 - 358.6 \, \text{kN} \cdot \text{m}) + (\frac{1}{2})(0.4)(2.37)(0.334) \]

\[ = 154.6 \, \text{kN}^2 + 1434 \, \text{kN} \cdot \text{m} = 797.7 = 12.1 + 7.26 \, (h - 1)^3 \]

\[ T_{W} = 7.26 \, h_1^3 + 133 \, h_1^2 - 1494 \, h_1 - 222 \]

4) SOLVE THE CUBIC BY TRIAL AND ERROR

\[ h_1 = 3.75' \quad \text{WEBS 3.75'} \]

5) DETERMINE REQUIREMENTS IF AN 8 IN. DIAMETER FELT IS USED

\[ L = \frac{h}{2} = 0.9 \]

\[ T_{W} = 30.0 \, h_2^2 + 787 \, h_2 - 44.4 + 12.1 = 7.26 \, (h - 1)^3 \]

\[ = 7.26 \, h_2^3 - 133 \, h_2^2 + 1494 \, h_2 - 222 \]

\[ h_2 = 8.4', \quad \text{TOO LARGE, 8 IN. FELTS ARE NOT FEASIBLE BY THEMSELVES.} \]
REFERENCES


