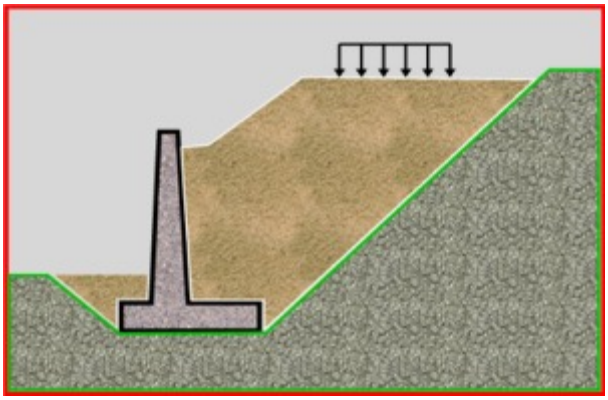
STRUCTWARE®

Program Documentation

for

RETAIN

Retaining Wall Design Program



CONTENTS

ITEM PAGE

Introduction…..... A-1

Program information

Online help file..... B1-1
Graphical interface..... B2-1

Verification problems..... C-1

INTRODUCTION

RETAIN may be used to design or review cantilevered concrete retaining walls and bridge abutments with either spread footing or pile foundations. The program supports both english and metric units. Concrete design may be performed using either the ultimate strength design procedure or the working stress design method. The soil configuration may either be constant sloped backfill with a uniform surcharge loading or an irregular backfill and surcharge load. A variety of loads may be specified on the wall, including axial dead and live load at the top which allows the program to simulate a bridge abutment loading.

The online help file and graphical interface is shown in Section B. Verification problems are included in Section C. Additional information is contained in the following files installed in the program directory.

License.txt - The license agreement contains the terms and conditions for use of this program and documentation.

Readme.txt – The installation instructions, copyright notices and version history is contained in this file.

The following steps are recommended for users new to the program or specific features.

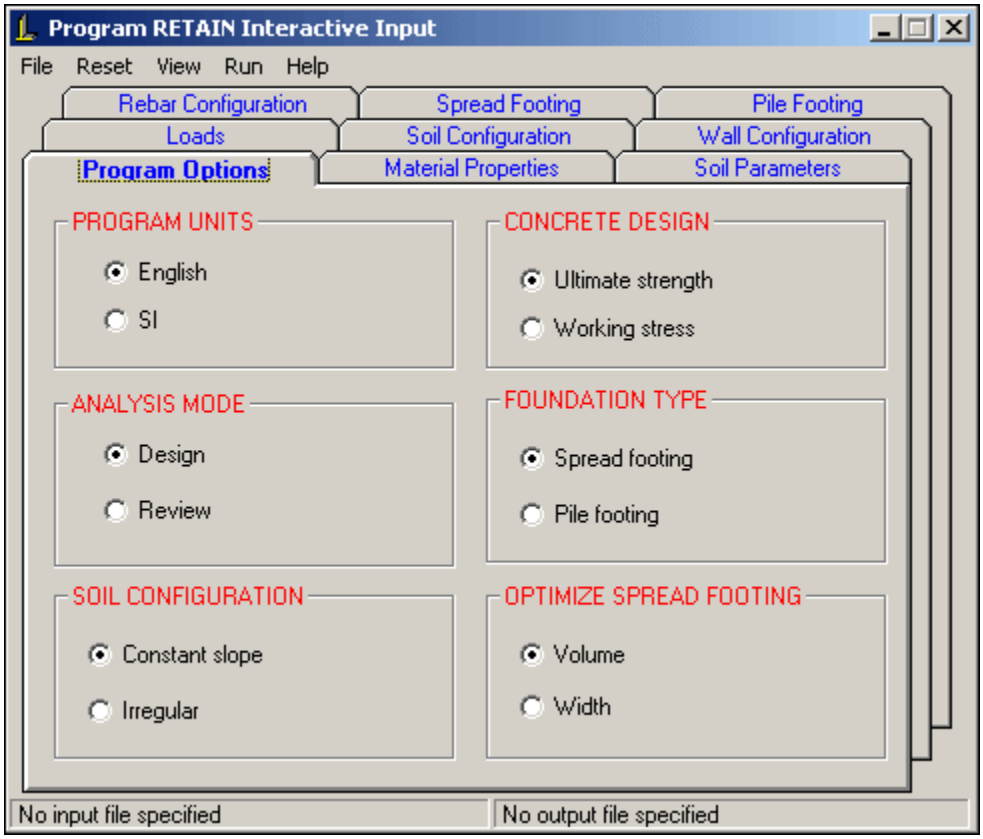
1. To learn how to use the program, view the Flash Demonstration Movie that is installed along with the program and read the "Instructions" section of the help file.

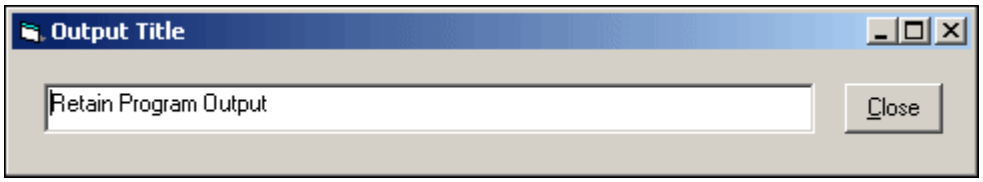
2. To apply this program to a specific problem, find a similar case in the Verification Problems section of this document. Run the program to see if you can reproduce the results. If your problem varies significantly from the Verification Problem, you should perform manual calculations for verification.

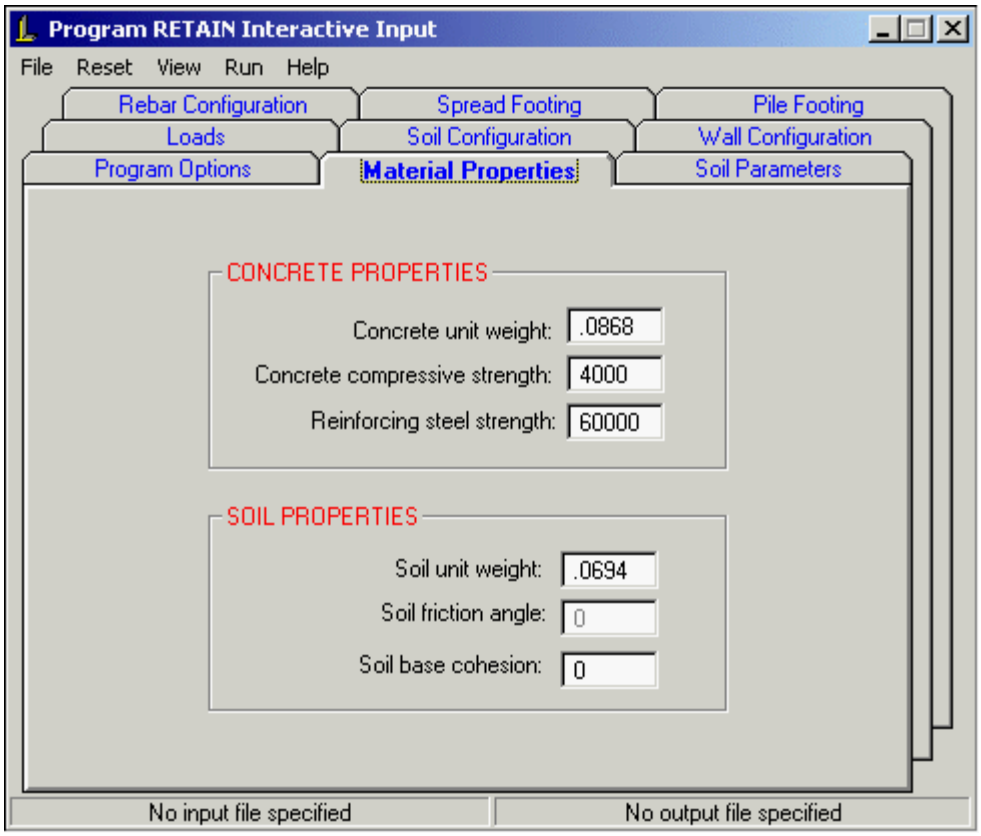
ONLINE HELP FILE

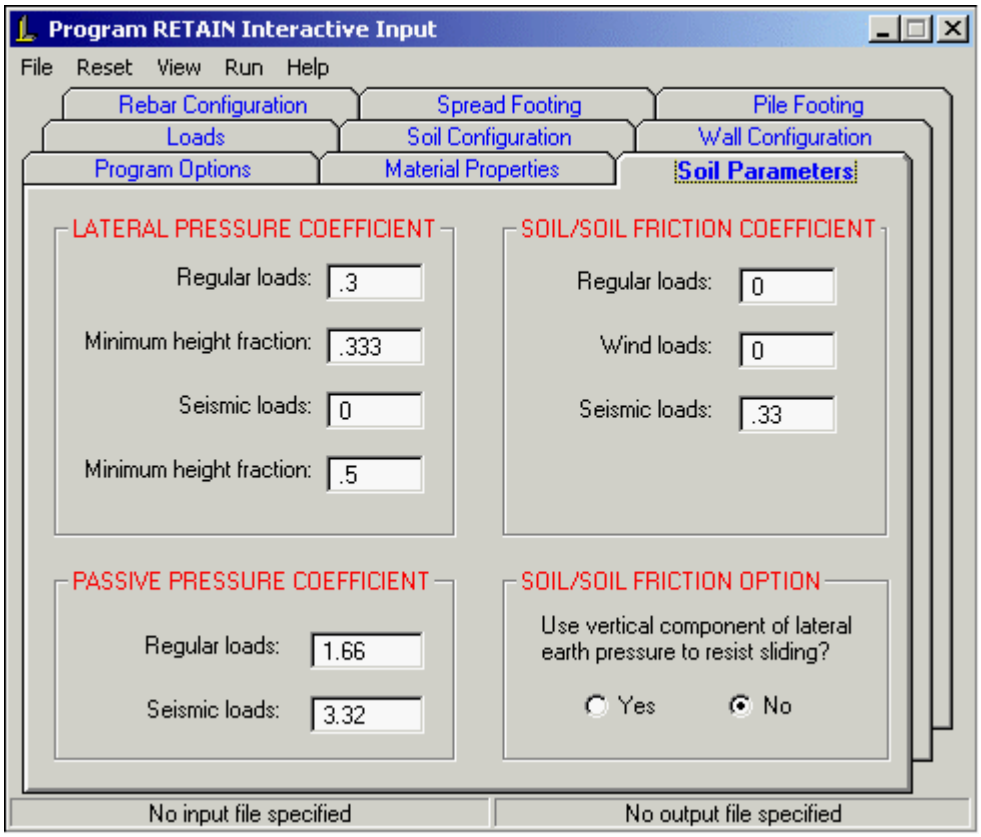
Retain help

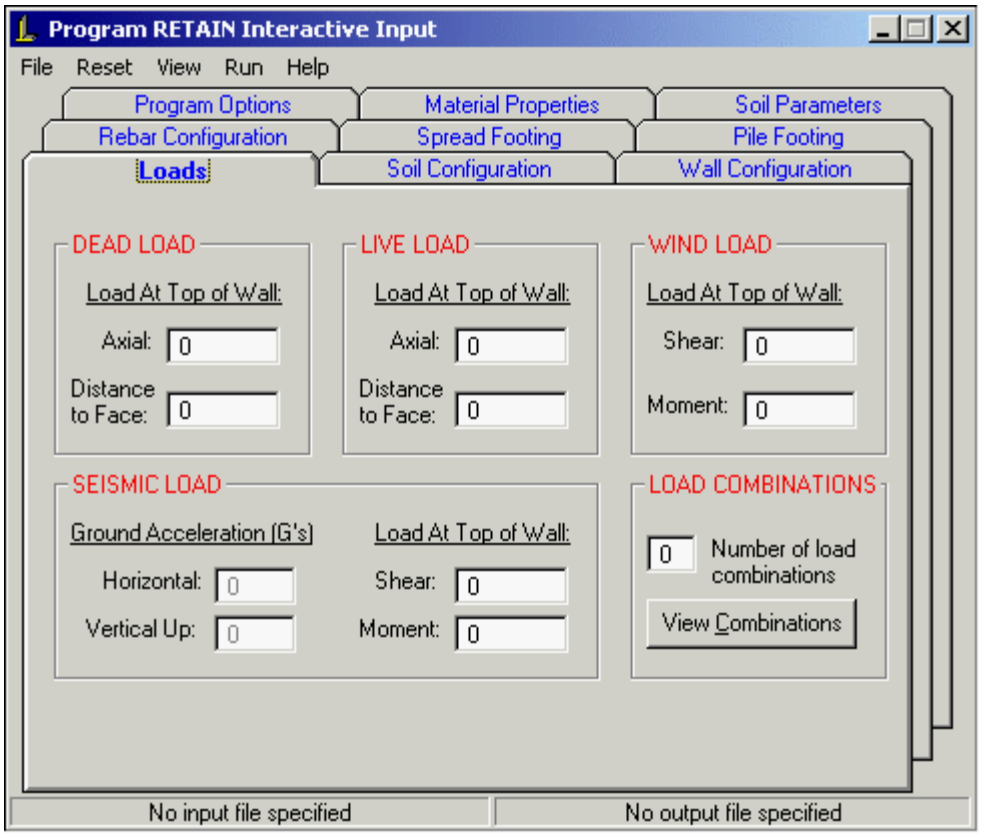
GRAPHICAL INTERFACE

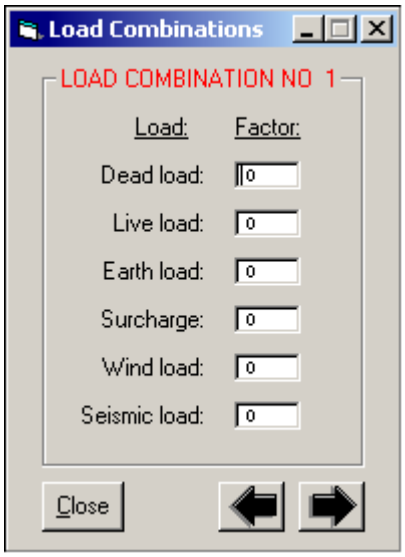


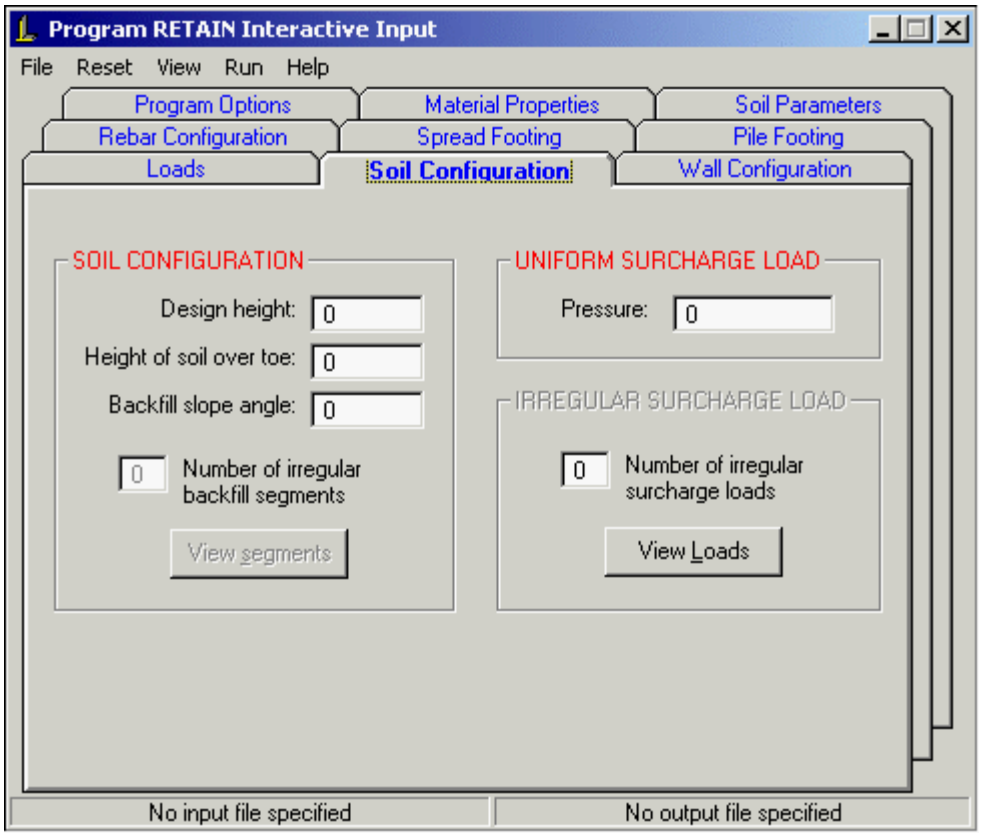


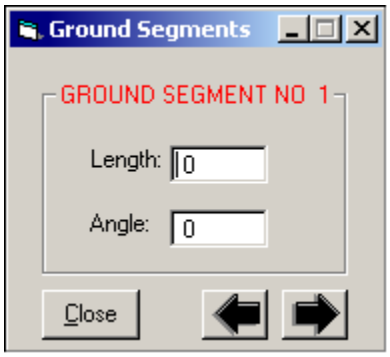

Program RETAIN Interactive Input
File Reset View Run Help
Rebar Configuration
Spread Footing
Pile Footing
Loads
Soil Configuration
Wall Configuration
Program Options
Material Properties
Soil Parameters
CONCRETE PROPERTIES
Concrete unit weight: .0868
Concrete compressive strength: 4000
Reinforcing steel strength: 60000
SOIL PROPERTIES
Soil unit weight: .0694
Soil friction angle: 0
Soil base cohesion: 0
No input file specified
No output file specified

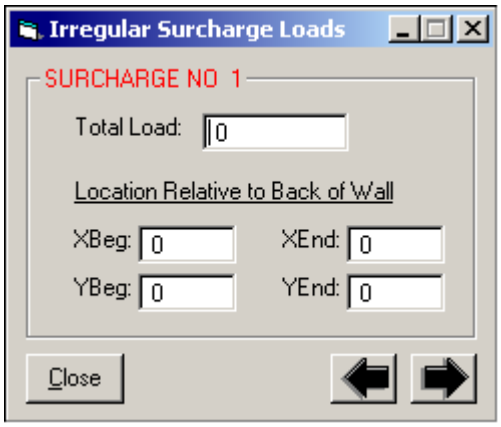

Program RETAIN Interactive Input
File Reset View Run Help
Rebar Configuration
Spread Footing
Pile Footing
Loads
Soil Configuration
Wall Configuration
Program Options
Material Properties
Soil Parameters
LATERAL PRESSURE COEFFICIENT
Regular loads: .3
Minimum height fraction: .333
Seismic loads: 0
Minimum height fraction: .5
SOIL/SOIL FRICTION COEFFICIENT
Regular loads: 0
Wind loads: 0
Seismic loads: .33
PASSIVE PRESSURE COEFFICIENT
Regular loads: 1.66
Seismic loads: 3.32
SOIL/SOIL FRICTION OPTION
Use vertical component of lateral earth pressure to resist sliding?
Yes
No
No input file specified
No output file specified

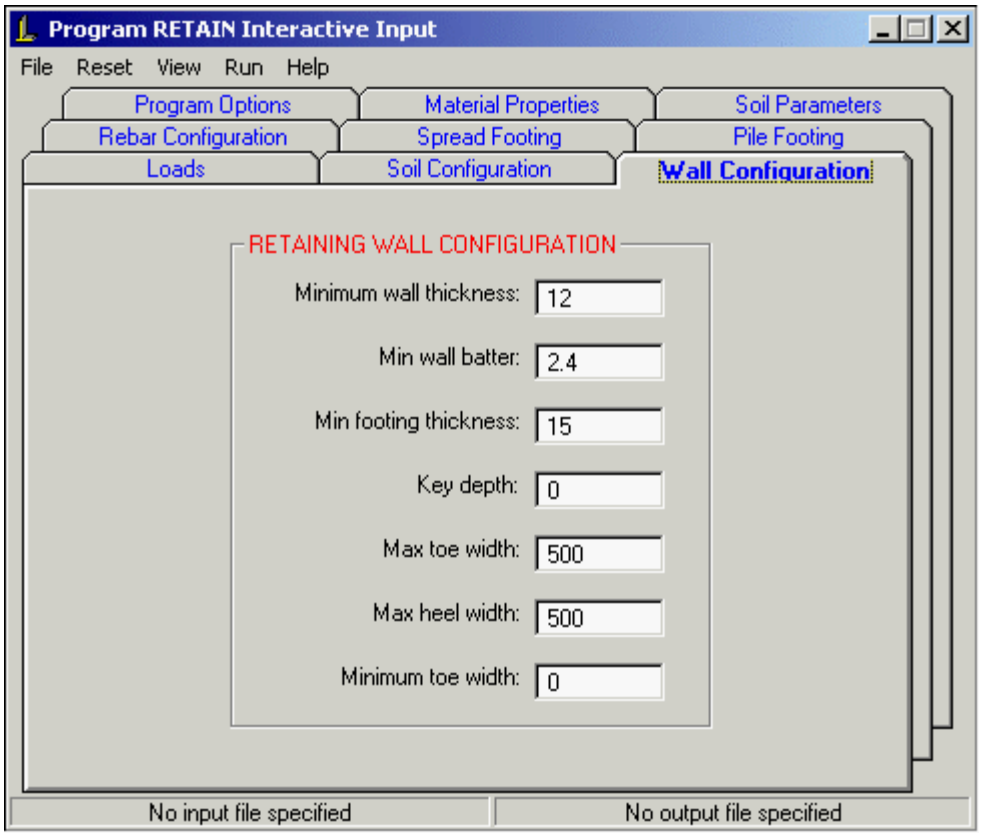

Program RETAIN Interactive Input
File
Reset
View
Run
Help
Program Options
Material Properties
Soil Parameters
Rebar Configuration
Spread Footing
Pile Footing
Loads
Soil Configuration
Wall Configuration
DEAD LOAD
Load At Top of Wall:
Axial:
0
Distance to Face:
0
LIVE LOAD
Load At Top of Wall:
Axial:
0
Distance to Face:
0
WIND LOAD
Load At Top of Wall:
Shear:
0
Moment:
0
SEISMIC LOAD
Ground Acceleration (G's)
Horizontal:
0
Vertical Up:
0
Load At Top of Wall:
Shear:
0
Moment:
0
LOAD COMBINATIONS
0
Number of load combinations
View Combinations
No input file specified
No output file specified

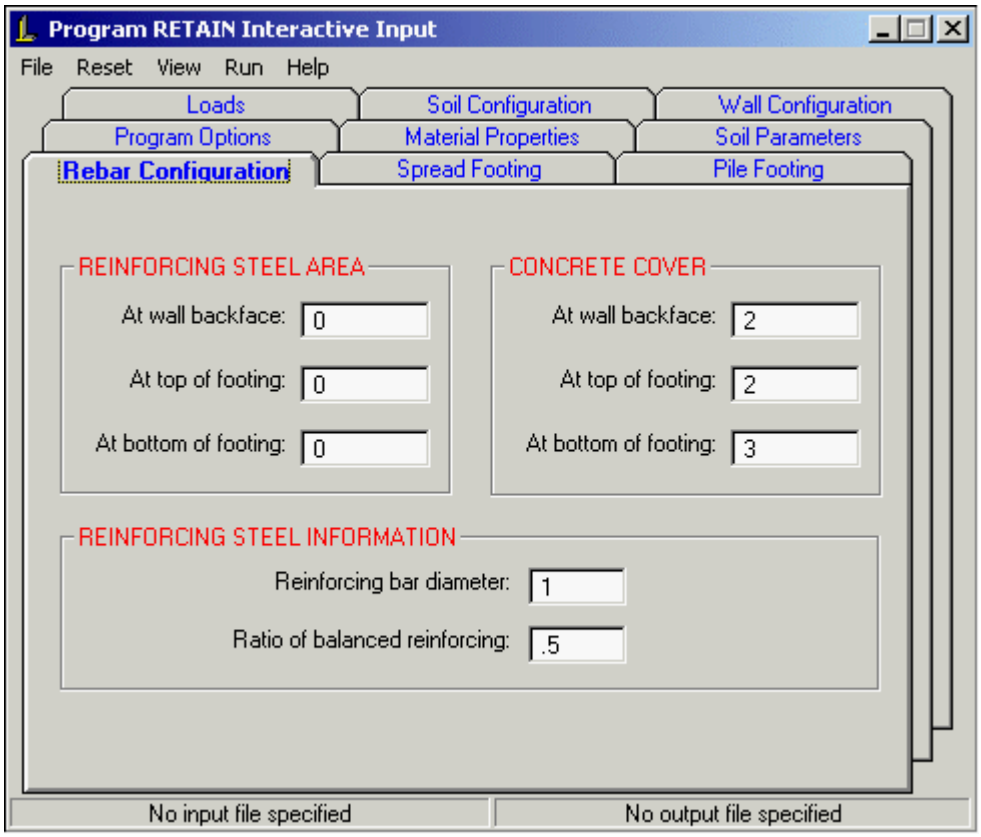

Load Combinations
LOAD COMBINATION NO 1
Load:
Factor:
Dead load:
0
Live load:
0
Earth load:
0
Surcharge:
0
Wind load:
0
Seismic load:
0
Close

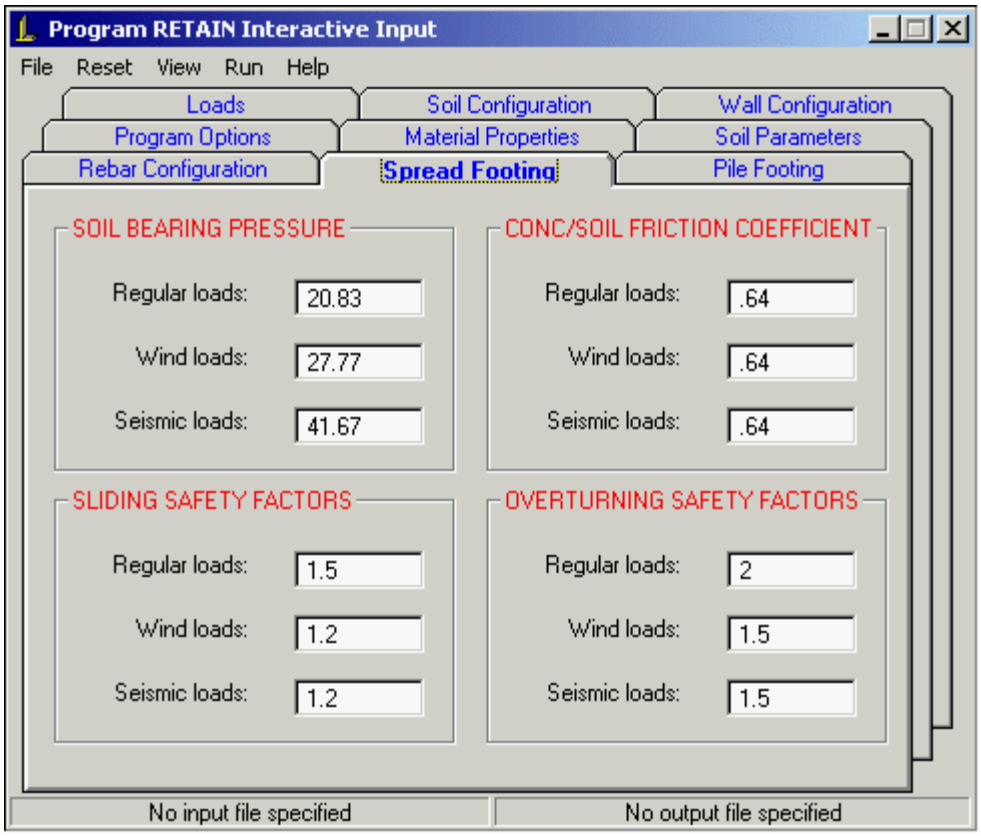

Program RETAIN Interactive Input
File Reset View Run Help
Program Options
Material Properties
Soil Parameters
Rebar Configuration
Spread Footing
Pile Footing
Loads
Soil Configuration
Wall Configuration
SOIL CONFIGURATION
Design height: 0
Height of soil over toe: 0
Backfill slope angle: 0
0 Number of irregular backfill segments
View segments
UNIFORM SURCHARGE LOAD
Pressure: 0
IRREGULAR SURCHARGE LOAD
0 Number of irregular surcharge loads
View Loads
No input file specified
No output file specified

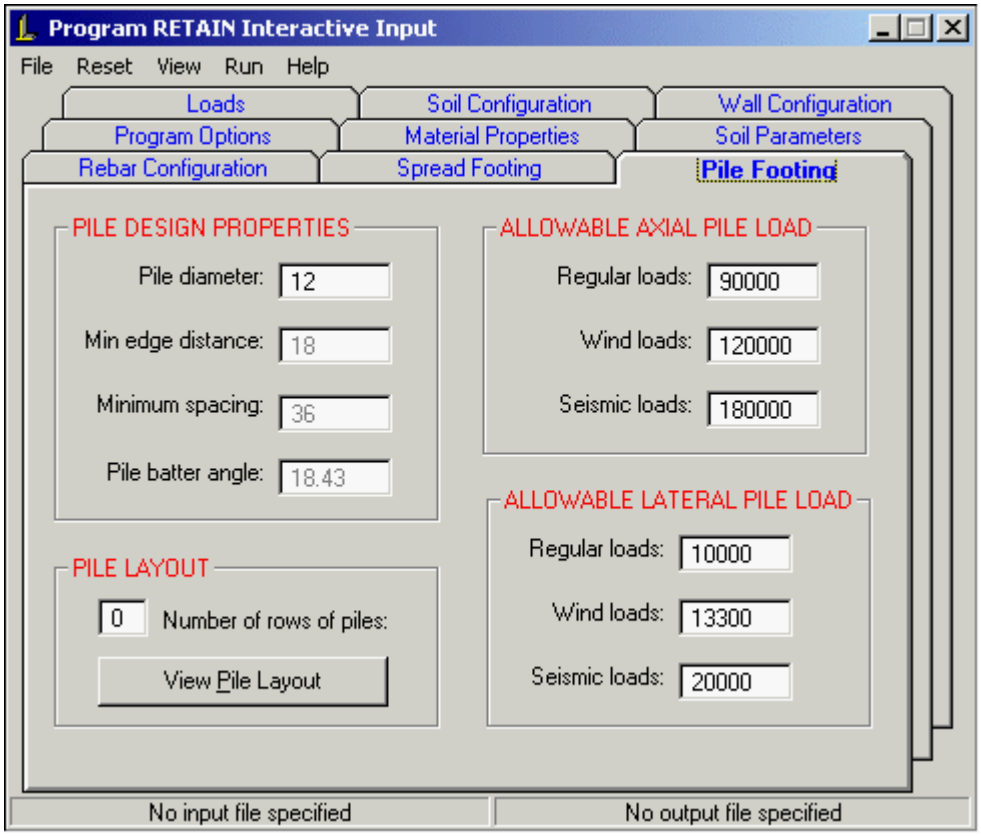

Ground Segments
GROUND SEGMENT NO 1
Length: 0
Angle: 0
Close

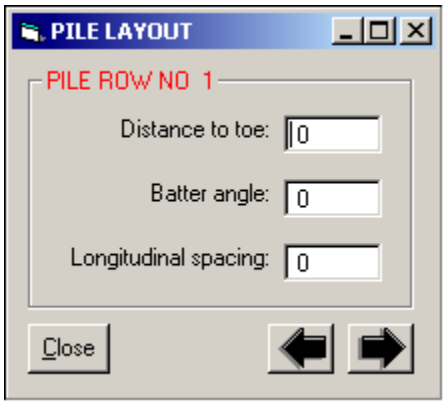

Irregular Surcharge Loads
SURCHARGE NO 1
Total Load: 0
Location Relative to Back of Wall
XBeg: 0
XEnd: 0
YBeg: 0
YEnd: 0
Close


Program RETAIN Interactive Input
File Reset View Run Help
Program Options
Material Properties
Soil Parameters
Rebar Configuration
Spread Footing
Pile Footing
Loads
Soil Configuration
Wall Configuration
RETAINING WALL CONFIGURATION
Minimum wall thickness: 12
Min wall batter: 2.4
Min footing thickness: 15
Key depth: 0
Max toe width: 500
Max heel width: 500
Minimum toe width: 0
No input file specified
No output file specified


Program RETAIN Interactive Input
File Reset View Run Help
Loads
Soil Configuration
Wall Configuration
Program Options
Material Properties
Soil Parameters
Rebar Configuration
Spread Footing
Pile Footing
REINFORCING STEEL AREA
At wall backface: 0
At top of footing: 0
At bottom of footing: 0
CONCRETE COVER
At wall backface: 2
At top of footing: 2
At bottom of footing: 3
REINFORCING STEEL INFORMATION
Reinforcing bar diameter: 1
Ratio of balanced reinforcing: .5
No input file specified
No output file specified


Program RETAIN Interactive Input
File
Reset
View
Run
Help
Loads
Soil Configuration
Wall Configuration
Program Options
Material Properties
Soil Parameters
Rebar Configuration
Spread Footing
Pile Footing
SOIL BEARING PRESSURE
Regular loads:
20.83
Wind loads:
27.77
Seismic loads:
41.67
CONC/SOIL FRICTION COEFFICIENT
Regular loads:
.64
Wind loads:
.64
Seismic loads:
.64
SLIDING SAFETY FACTORS
Regular loads:
1.5
Wind loads:
1.2
Seismic loads:
1.2
OVERTURNING SAFETY FACTORS
Regular loads:
2
Wind loads:
1.5
Seismic loads:
1.5
No input file specified
No output file specified


Program RETAIN Interactive Input
File Reset View Run Help
Loads
Soil Configuration
Wall Configuration
Program Options
Material Properties
Soil Parameters
Rebar Configuration
Spread Footing
Pile Footing
PILE DESIGN PROPERTIES
Pile diameter: 12
Min edge distance: 18
Minimum spacing: 36
Pile batter angle: 18.43
ALLOWABLE AXIAL PILE LOAD
Regular loads: 90000
Wind loads: 120000
Seismic loads: 180000
ALLOWABLE LATERAL PILE LOAD
Regular loads: 10000
Wind loads: 13300
Seismic loads: 20000
PILE LAYOUT
0 Number of rows of piles:
View Pile Layout
No input file specified
No output file specified


PILE LAYOUT
PILE ROW NO 1
Distance to toe: 0
Batter angle: 0
Longitudinal spacing: 0
Close

VERIFICATION PROBLEMS

1. Caltrans Soundwall on Retaining Wall

   A. English units
   B. Review mode
   C. Working stress design
   D. Constant slope
   E. Spread footing

2. Army Corps of Engineers Channel Wall

   A. Metric units
   B. Review mode
   C. Ultimate strength design
   D. Irregular backfill
   E. Spread footing

3. Railroad Retaining Wall

   A. Metric units
   B. Design mode
   C. Ultimate strength design
   D. Irregular backfill
   E. Spread footing

4. Caltrans Earthquake Resistant Retaining Wall

   A. English units
   B. Review mode
   C. Ultimate strength design
   D. Constant slope
   E. Spread footing

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C1-1 OF _____

TITLE _____ BY Rm DATE 11/7/96

Verification Problem no. 1

Review Caltrans "Soundwall on Retaining Wall" design
Sheet xs 3-51 (English)

Design H = 10' SC = 2'

PD = (1414 + 372)/12 = 148.8 lbs
PDX = 4"

VW = 30 x 16/12 = 40 lbs
MW = 40 x 16 x 12/2 = 3840 in-lbs

VEQ = 148.8 x .3 = 44.6 lbs
MEQ = 44.6 x 16 x 12/2 = 4285 in-lbs

Load combinations:

1) 1.0D + 1.0E + 1.0SC
2) .75D + .75E + .75SC + .75W (33% increase allowed)
3) .75D + .75E + .75EQD — No seismic earth load

Q = 3000/144 = 20.83
QW = 3990/144 = 27.71
QEQ = 3990/144 = 27.71

CS = .67

Asw = .31 x 2/12 = .0517

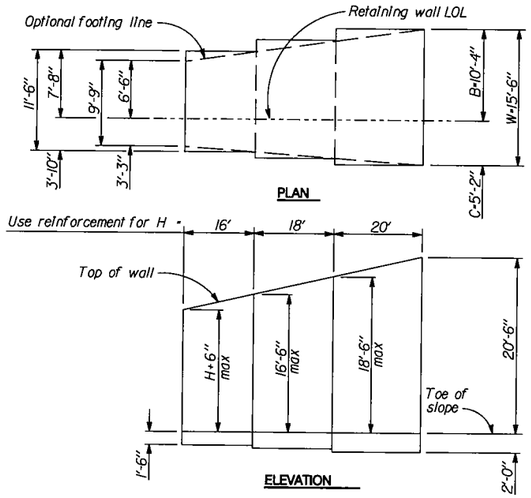
RELEASED 8-19-92

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

REGISTERED ENGINEER - CIVIL

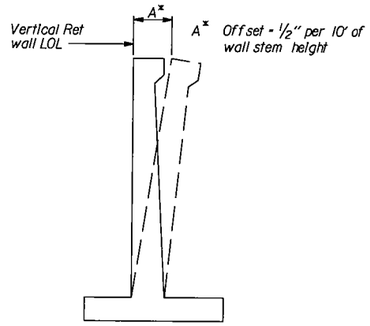
REGISTERED PROFESSIONAL ENGINEER — No. ____ Exp. ____ CIVIL — STATE OF CALIFORNIA

PLANS APPROVAL DATE



TYPICAL LAYOUT EXAMPLE

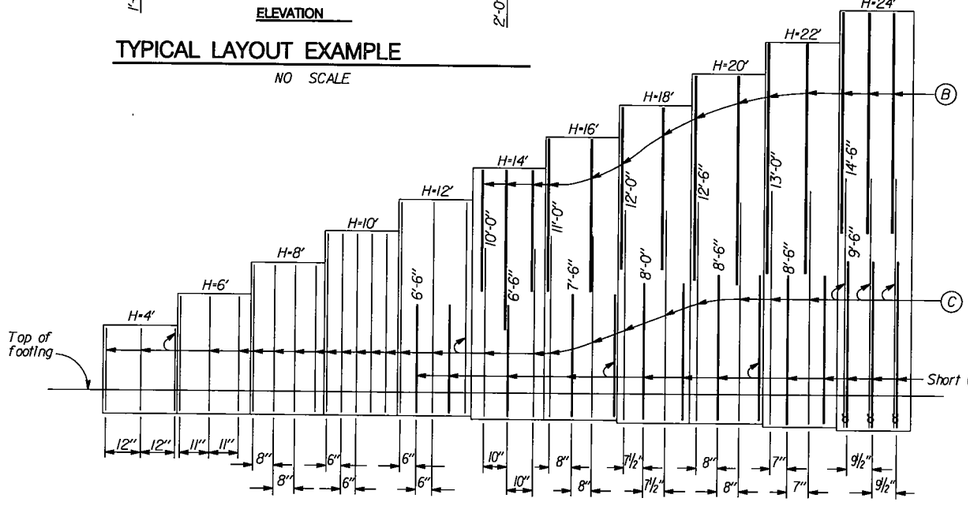
NO SCALE



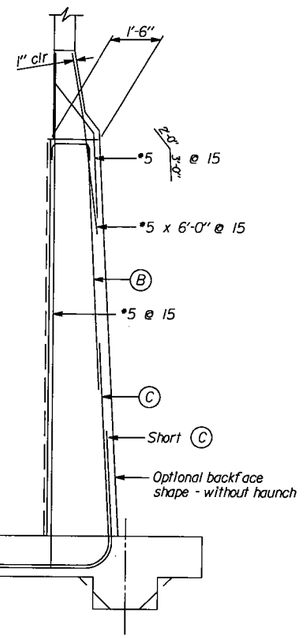
WALL OFFSET

NO SCALE

Values for offsetting forms to be determined by the Engineer



ELEVATION



OPTIONAL SPREAD FOOTING SECTION

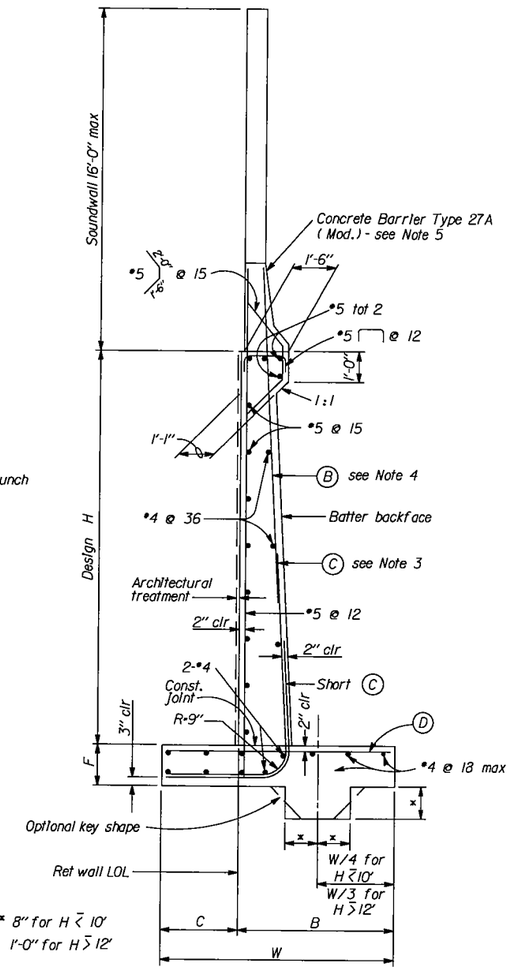
NO SCALE

For details not shown, see "SPREAD FOOTING SECTION" detail

NOTE:

8 - Bundle bars

Numbers above (C) bars indicate distance from top of footing to upper end of (C) bars



SPREAD FOOTING SECTION

NO SCALE

DESIGN DATA

REINFORCED CONCRETE

fs = 24000 psi f'c = 3250 psi
fc = 1300 psi n = 10

EARTH = 120 pcf
LIVE LOAD = 2' SURCHARGE
EQUIVALENT FLUID PRESSURE
- 36 pcf MAX FOR DETERMINATION OF TOE PRESSURE
- 27 pcf MAX FOR DETERMINATION OF HEEL PRESSURE

LEVEL SLOPE

SEISMIC LOAD = 0.3 DEAD LOAD
WIND LOAD = 30 psf
DEAD LOAD OF SOUNDWALL = 1414 lb/lf
DEAD LOAD OF BARRIER = 372 lb/lf

DESIGN CONDITIONS

DESIGN H MAY BE EXCEEDED BY 6" BEFORE GOING TO THE NEXT DESIGN H

SPECIAL FOOTING DESIGN IS REQUIRED WHERE FOUNDATION MATERIAL IS INCAPABLE OF SUPPORTING THE TOE PRESSURE LISTED IN TABLE

LOADING COMBINATION	PERCENTAGE OF BASIC UNIT STRESS
GROUP 1: D + E + SC	100
GROUP 2: D + E + SC + W	133
GROUP 3: D + E + EQD	133

D = DEAD LOAD
E = LATERAL EARTH PRESSURE
SC = LIVE LOAD SURCHARGE
W = WIND LOAD
EQD = SEISMIC DEAD LOAD

TABLE OF REINFORCING STEEL DIMENSIONS AND DATA

DESIGN H		4	6	8	10	12	14	16	18	20	22	24
W		5'-6"	6'-0"	6'-8"	7'-6"	8'-8"	9'-9"	11'-6"	13'-6"	15'-6"	17'-9"	20'-3"
C		1'-10"	2'-0"	2'-3"	2'-6"	2'-11"	3'-3"	3'-10"	4'-6"	5'-2"	5'-11"	6'-9"
B		3'-8"	4'-0"	4'-5"	5'-0"	5'-9"	6'-6"	7'-8"	9'-0"	10'-4"	11'-10"	13'-6"
F SPREAD FTG		1'-3"	1'-3"	1'-3"	1'-3"	1'-3"	1'-4"	1'-6"	1'-8"	2'-0"	2'-4"	2'-8"
STEM WITH HAUNCH, BATTER		1/2 :12	1/2 :12	1/2 :12	1/2 :12	1/2 :12	1/2 :12	1/2 :12	5/8 :12	3/4 :12	7/8 :12	1 :12
STEM WITHOUT HAUNCH, BATTER							1/4 :12	1/4 :12	1/4 :12	1/2 :12	5/8 :12	3/4 :12
(B) BARS							*5 @ 10	*7 @ 16	*7 @ 15	*8 @ 16	*8 @ 14	*7 @ 9½
(C) BARS		*5 @ 12	*5 @ 11	*5 @ 8	*5 @ 6	*6 @ 6	*9 @ 10	*9 @ 8	*10 @ 7½	*11 @ 8	*11 @ 7	*10 @ 9½ 8
(D) BARS		*4 @ 12	*4 @ 11	*4 @ 8	*5 @ 6	*5 @ 6	*8 @ 10	*7 @ 8	*9 @ 7½	*9 @ 8	*10 @ 7	*11 @ 9½
2' Level surchg	Toe Pr. k/sf	2.9	2.9	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0

NOTES:

1. FOR SOUNDWALL AND RETAINING WALL ARCHITECTURAL TREATMENT, SEE DETAILS ELSEWHERE IN PROJECT PLANS
2. FOR DETAILS NOT SHOWN AND DRAINAGE NOTES, SEE (B3-8)
3. FOR H-4 THRU H-12, EXTEND BARS TO TOP OF CONCRETE BARRIER
4. FOR H-14 THRU H-24, EXTEND BARS TO TOP OF CONCRETE BARRIER
5. FOR LONGITUDINAL REINFORCEMENT, SEE DETAILS ELSEWHERE IN PROJECT PLANS

STANDARD DRAWING

FILE NO. XS 3-51	DESIGN BY C.E. Roworth	CHECKED A. Salerno	APPROVAL RECOMMENDED BY
DESIGN DATE 7/92	DETAILS BY R. Yee	CHECKED	DESIGN SUPERVISOR
	SUBMITTED BY J.C. Moese		

DS OSD 2147A (CADD 4/89)

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DIVISION OF STRUCTURES
STRUCTURE DESIGN

CU
EA

BRIDGE NO.
POST MILE

SOUNDWALL ON RETAINING WALL

DISREGARD PRINTS BEARING EARLIER REVISION DATES →

REVISION DATES (PRELIMINARY STAGE ONLY)	SHEET	OF

XS351.DGN VI-1

RETAIN PROGRAM OUTPUT

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   R E T A I N                   *
*                                                         *
*                 INPUT DATA ECHO                         *
*                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
(Version  1.42)                5/02/2007,  5:07:52

Input file  = V1.IN
Output file = V1_1.42.out

P R O G R A M   O P T I O N S
=====================================================

PROGRAM UNITS      =  1 (English: inches/pounds/degrees)
ANALYSIS MODE      =  2 (Review)
CONCRETE DESIGN    =  2 (Working stress)
SOIL CONFIGURATION =  1 (Constant slope)
FOUNDATION TYPE    =  1 (Spread footing)

M A T E R I A L   P R O P E R T I E S
=====================================================

CONCRETE PROPERTIES:

     Concrete unit weight          = 0.8680E-01
     Concrete compressive strength =  3250.
     Reinforcing steel strength    = 0.6000E+05

SOIL PROPERTIES:

     Soil unit weight              = 0.6940E-01
     Soil friction angle           =  0.000
     Soil base cohesion            =  0.000

S O I L   P A R A M E T E R S
=====================================================

LATERAL PRESSURE COEFFICIENT:

     Regular loads =  0.300  @ Y =  0.333H
     Seismic loads =  0.000  @ Y =  0.500H

PASSIVE PRESSURE COEFFICIENT:

     Regular loads =  1.667
     Seismic loads =  3.333
```

```
SOIL/SOIL FRICTION COEFFICIENT:

     Regular loads =  0.000
     Wind loads    =  0.000
     Seismic loads =  0.000

SOIL/SOIL FRICTION OPTION:

     Option        =  0 (No Pa vert component)

L O A D S
==================================================

LOADS AT TOP OF WALL:

     Dead load      =  148.8      @ X =  4.000
     Live load      =  0.000      @ X =  0.000
     Wind shear     =  40.00
     Wind moment    =  3840.
     Seismic shear  =  44.60
     Seismic moment =  4285.

LOAD COMBINATIONS:

      1.000D + 0.000L + 1.000E + 1.000SC + 0.000W + 0.000EQ
      0.750D + 0.000L + 0.750E + 0.750SC + 0.750W + 0.000EQ
      0.750D + 0.000L + 0.750E + 0.000SC + 0.000W + 0.750EQ

S O I L   C O N F I G U R A T I O N
==================================================

Design height           =  120.0
Height of soil over toe =  0.000
Backfill slope angle    =  0.000

Uniform surcharge       =  1.667

W A L L   C O N F I G U R A T I O N
==================================================

Minimum wall thickness    =  12.00
Wall batter               =  2.400
Footing thickness         =  15.00
Key depth                 =  8.000
Toe width                 =  30.00
Footing width             =  90.00

R E B A R   C O N F I G U R A T I O N
==================================================

REINFORCING STEEL INFORMATION:

     Bar diameter           = 0.6250
```

```
     Ratio of balanced reinf = 0.5000

CONCRETE COVER:

     At wall backface        =  2.000
     At footing top          =  2.000
     At footing bottom       =  3.000

REINFORCING STEEL AREA:

     At wall backface        = 0.5170E-01
     At footing top          = 0.5170E-01
     At footing bottom       = 0.5170E-01

S P R E A D   F O O T I N G
==================================================

ALLOWABLE SOIL BEARING PRESSURE:

     Regular loads =  20.83
     Wind loads    =  27.71
     Seismic loads =  27.71

CONCRETE/SOIL FRICTION COEFFICIENT:

     Regular loads =  0.670
     Wind loads    =  0.670
     Seismic loads =  0.670

OVERTURNING SAFETY FACTORS:

     Regular loads =  2.000
     Wind loads    =  1.500
     Seismic loads =  1.500

SLIDING SAFETY FACTORS:

     Regular loads =  1.500
     Wind loads    =  1.200
     Seismic loads =  1.200

* * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                     *
*           P R O G R A M   R E T A I N               *
*                                                     *
*                   OUTPUT DATA                       *
*                                                     *
* * * * * * * * * * * * * * * * * * * * * * * * * * * *

W A L L   D E S I G N
==================================================
```

```
LOAD COMBINATION   1:

  Shear  =  209.9
  Moment =  9591.

LOAD COMBINATION   2:

  Shear  =  187.4
  Moment = 0.1367E+05

LOAD COMBINATION   3:

  Shear  =  145.9
  Moment = 0.1172E+05

MAXIMUM LOADS:

  Shear  =  209.9
  Moment = 0.1367E+05

    Shear capacity     =  797.0     > Design shear     =  209.9     OKAY
    Stress in steel    = 0.1940E+05 < Allowable stress = 0.2400E+05 OKAY
    Stress in concrete =  616.7     < Allowable stress =  1300.     OKAY

W A L L   L O A D   D I S T R I B U T I O N
==================================================

     DEPTH     SHEAR    MOMENT     THICK   AS REQD

       24.       43.     4053.    13.005     0.018
       48.       66.     5107.    14.011     0.020
       72.       97.     6984.    15.016     0.026
       96.      144.     9791.    16.021     0.033
      120.      210.    13678.    17.027     0.043

W E I G H T   A N D   R I G H T I N G   M O M E N T
==================================================

DEAD LOAD       =  796.0
RIGHTING MOMENT = 0.4144E+05

LIVE LOAD       =  0.000
RIGHTING MOMENT =  0.000

SURCHARGE LOAD  =  80.02
RIGHTING MOMENT =  5281.

E X T E R N A L   S T A B I L I T Y   A N A L Y S I S
==================================================

LOAD COMBINATION   1:

  Lateral force      =  257.2
```

```
    Overturning moment = 0.1309E+05
    Total weight       =  876.0
    Righting moment    = 0.4673E+05
    Sliding resistance =  617.5

    Sliding SF         =   2.40     >   1.50     OKAY
    Overturning SF     =   3.57     >   2.00     OKAY

    SOIL PRESSURE:

      Eccentricity  =  6.598
      Toe pressure  =  14.01
      Heel pressure =  5.452

      Max pressure  =  14.01     <  20.83     OKAY

  LOAD COMBINATION   2:

    Lateral force      =  297.2
    Overturning moment = 0.2233E+05
    Total weight       =  876.0
    Righting moment    = 0.4673E+05
    Sliding resistance =  617.5

    Sliding SF         =   2.08     >   1.20     OKAY
    Overturning SF     =   2.09     >   1.50     OKAY

    SOIL PRESSURE:

      Eccentricity  =  17.15
      Toe pressure  =  20.97
      Footing is in partial compression

      Max pressure  =  20.97     <  27.71     OKAY

  LOAD COMBINATION   3:

    Lateral force      =  234.3
    Overturning moment = 0.1883E+05
    Total weight       =  796.0
    Righting moment    = 0.4144E+05
    Sliding resistance =  594.5

    Sliding SF         =   2.54     >   1.20     OKAY
    Overturning SF     =   2.20     >   1.50     OKAY

    SOIL PRESSURE:

      Eccentricity  =  16.59
      Toe pressure  =  18.68
      Footing is in partial compression

      Max pressure  =  18.68     <  27.71     OKAY
```

```
F O O T I N G   D E S I G N
====================================================

LOAD COMBINATION   1:

  Lateral force      =  257.2
  Overturning moment = 0.1309E+05
  Weight             =  876.0
  Righting moment    = 0.4673E+05

  SOIL PRESSURE:

    Eccentricity  =  6.598
    Toe pressure  =  14.01
    Heel pressure =  5.452

  FOOTING TOE:

    Shear  =  338.6
    Moment =  5292.

    Shear capacity     =  633.0     > Design shear     =  338.6     OKAY
    Stress in steel    =  9535.     < Allowable stress = 0.2400E+05 OKAY
    Stress in concrete =  345.3     < Allowable stress =  1300.     OKAY

  FOOTING HEEL:

    Shear  =  163.3
    Moment =  4138.

    Shear capacity     =  687.1     > Design shear     =  163.3     OKAY
    Stress in steel    =  6847.     < Allowable stress = 0.2400E+05 OKAY
    Stress in concrete =  236.7     < Allowable stress =  1300.     OKAY

LOAD COMBINATION   2:

  Lateral force      =  222.9
  Overturning moment = 0.1674E+05
  Weight             =  657.0
  Righting moment    = 0.3504E+05

  SOIL PRESSURE:

    Eccentricity  =  17.15
    Toe pressure  =  15.72
    Footing is in partial compression

  FOOTING TOE:

    Shear  =  357.8
    Moment =  5790.
```

```
      Shear capacity     =  633.0     > Design shear     =  357.8     OKAY
      Stress in steel    = 0.1043E+05 < Allowable stress = 0.2400E+05 OKAY
      Stress in concrete =  377.8     < Allowable stress =  1300.     OKAY

    FOOTING HEEL:

      Shear  =  238.5
      Moment =  6293.

      Shear capacity     =  687.1     > Design shear     =  238.5     OKAY
      Stress in steel    = 0.1041E+05 < Allowable stress = 0.2400E+05 OKAY
      Stress in concrete =  359.9     < Allowable stress =  1300.     OKAY

  LOAD COMBINATION   3:

    Lateral force      =  175.7
    Overturning moment = 0.1413E+05
    Weight             =  597.0
    Righting moment    = 0.3108E+05

    SOIL PRESSURE:

      Eccentricity  =  16.59
      Toe pressure  =  14.01
      Footing is in partial compression

    FOOTING TOE:

      Shear  =  317.0
      Moment =  5126.

      Shear capacity     =  633.0     > Design shear     =  317.0     OKAY
      Stress in steel    =  9235.     < Allowable stress = 0.2400E+05 OKAY
      Stress in concrete =  334.5     < Allowable stress =  1300.     OKAY

    FOOTING HEEL:

      Shear  =  190.5
      Moment =  5142.

      Shear capacity     =  687.1     > Design shear     =  190.5     OKAY
      Stress in steel    =  8508.     < Allowable stress = 0.2400E+05 OKAY
      Stress in concrete =  294.1     < Allowable stress =  1300.     OKAY
```

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C1-10 OF_____

TITLE PROGRAM "RETAIN" CHECK BY K CHONG DATE 11/18/96

CHECK : VERIFICATION PROBLEM NO 1

CHECK ON CALTRANS "SOUNDWALL ON RETAINING WALL" DESIGN SHEET

FOR DESIGN HEIGHT = 10'-0"

SURCHARGE = 2'

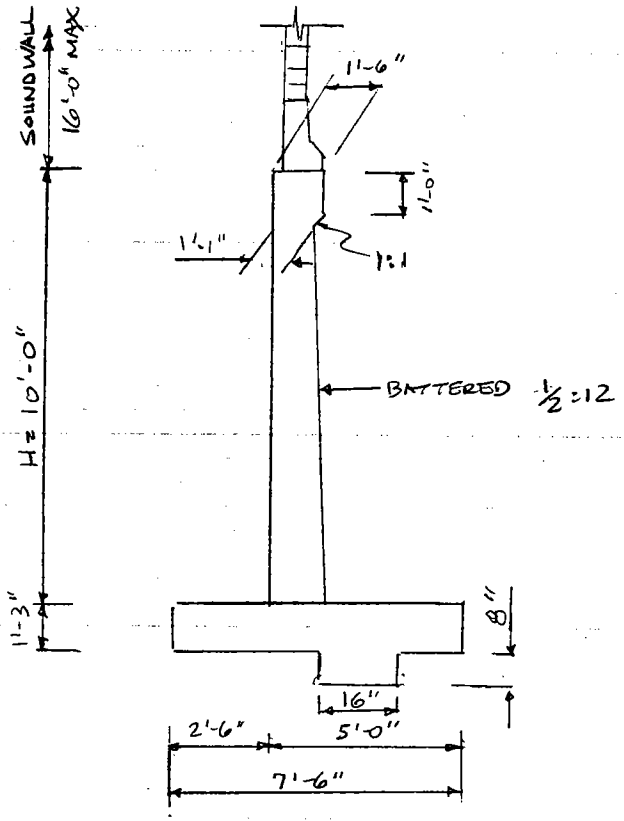


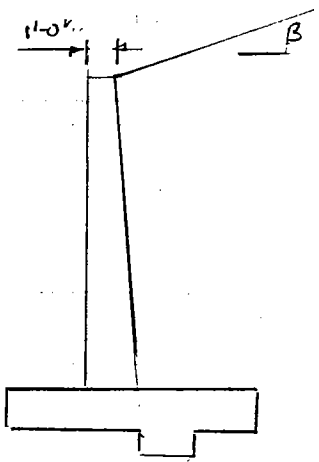
FIG 1.0

FOR DESIGN:

$\gamma_{CONCRETE} = 150\ lb/ft^3$

$f'_c = 3250\ psi$

$f_y = 60\ ksi$



LOAD COMBINATIONS

1.) 1.0D + 1.0E + 1.0 Sc

2.) 0.75D + 0.75E + 0.75 Sc + 0.75 W
(33% INCREASE ALLOWED)

3) 0.75D + 0.75E + 0.75 EQD
(NO SEISMIC EARTH LOAD)

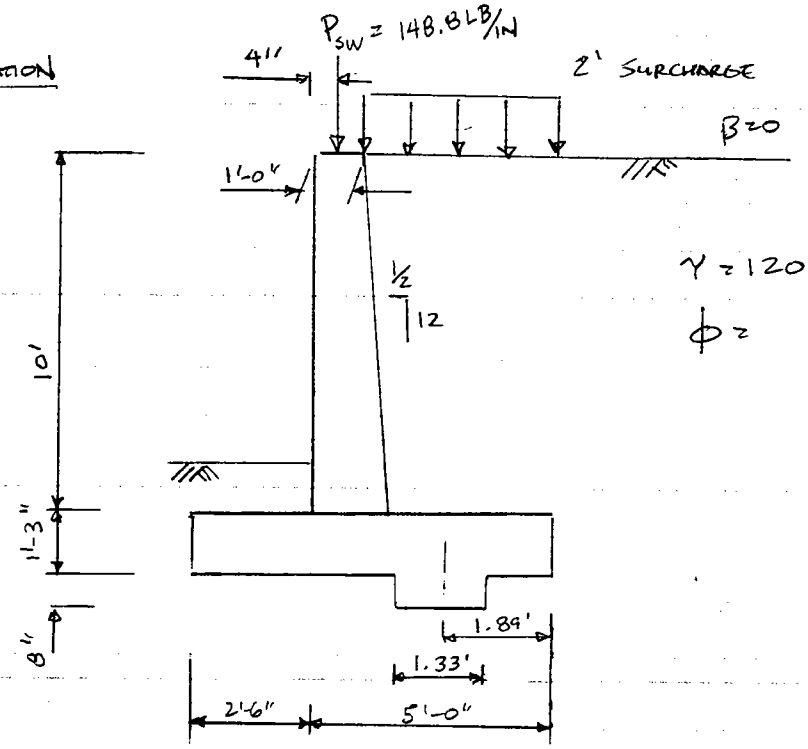
x IGNORE HAUNCH

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET C1-11 OF_____

TITLE_____ BY K-CHONG DATE 11/18/96

CONFIGURATION



$\gamma = 120\ lb/ft^3$

$\phi =$

CHECK STABILITY

ABOUT THE TOE

	COMPONENT	WEIGHT (lb/ft)	ARM (FT)	MOMENT (LB-ft)
1	STEM	$1 \times 10 \times 150\ lb/ft^3 = 1500$	3.0	4500
2	STEM (BATTERED)	$\frac{1}{2} \times 0.42 \times 10 \times 150\ lb/ft^3 = 315$	3.64	1146
3	FOOTING	$1.25 \times 7.5 \times 150\ lb/ft^3 = 1406$	3.75	5273
4	KEY	$1.33 \times 0.67 \times 150\ lb/ft^3 = 134$	5.61	752
5	SOIL (BACK)	$3.58 \times 10 \times 120\ lb/ft^3 = 4296$	5.71	24,530
6.	SOIL (BACK) BATTERED	$\frac{1}{2} \times 0.42 \times 10 \times 120\ lb/ft^3 = 252$	3.78	953
7.	SURCHARGE	$2 \times 4 \times 120\ lb/ft^3 = 960$	5.5	5280
8.	SOUNDWALL	$148.8\ LB/IN \times 12\ IN/ft = 1785$	2.83	5058

ΣW_{DL} (1-6) = 7903 LB $\Sigma W = 8863$ LB ΣM_R (SOIL + RW) = 37,154

$W_{SC} = 960$ lb $W_{SC} = 5080$ lb-ft

ACTIVE FORCE: $K_a = 0.30$

$P_a = \frac{1}{2} \gamma K_a H^2 = \frac{1}{2} (120\ lb/ft^3)(0.30)(11.25\ ft)^2$

$P_a = 12278\ lb/ft$

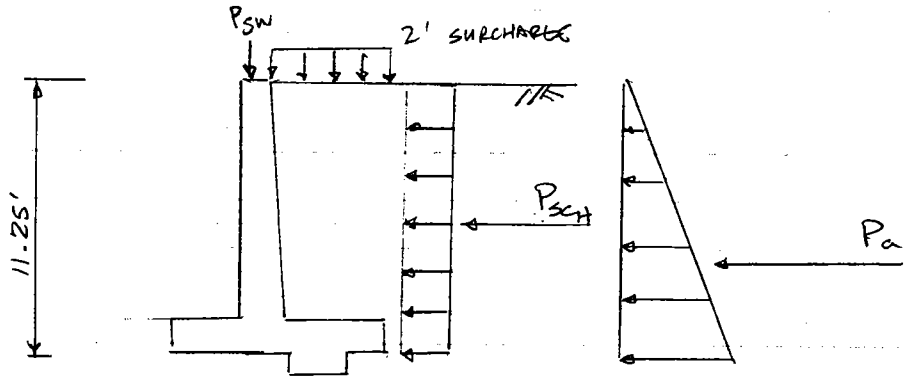
CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET BC1-12 OF_____

TITLE_____ BY K CHONG DATE 11/18/96

STABILITY CHECK

LATERAL FORCE DISTRIBUTION



P_a = 2278 lb/ft

$P_{SCH} = 0.3 \gamma h_{sc} \times H = 0.3\,(120\ lb/ft^3)(2ft) \times (11.25ft)$

$= 810\ lb/ft$

LOAD COMBINATION 1

1.0D + 1.0E + 1.0SC

DEAD LOAD: $\Sigma W_{RETWAL} + \Sigma W_{SOIL} + W_{SW} = 7903\ LB + 1785\ LB$

$= 9688\ LB/ft$

$= 807\ LB/IN \approx 796\ LB/IN$ ∴ OK

RESISTING MOMENT DUE TO DEAD LOAD = ΣM_R (DUE TO DL)

$= 37,154 + 4909$

$= 42,063\ LB\text{-}ft/ft = 42063\ LB\text{-}IN$

SURCHARGE LOAD = 1960 LB/ft = 80 LB/IN

$M_{SURCHARGE\ LOAD} = 5281\ LB\text{-}ft/ft$

$= 5281\ LB\text{-}IN$

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET 4C1-13 OF_____

TITLE_____ BY K. CHONG DATE 11/18/96

OVERTURNING STABILITY

LATERAL FORCE = $P_a + P_{SURCH}$ = 2278 lb/ft + 810 lb/ft
= 3088 lb/ft = 257.3 LB/IN

ΣM_D = (2278 lb/ft × 1 ft/12 in) × (11.25 ft × 12 in/ft / 3) + (810 lb/ft × 1 ft/12 in) × (11.25/2 × 12)
= 8542.5 lb-in + 4556.3 lb-in
= 13,099 lb-in (OVERTURNING MOMENT)

$\Sigma M_R = M_{RW+SOIL} + M_{SC} + M_{SW}$
= 37,154 lb-in + 5280 lb-in + 508
= 47,492 lb-in
(NOTE: KEY WAS INCLUDED)
FOR THIS ANALYSIS KEY WILL BE IGNORED

ΣM_R = 47,492 lb-in − 752 lb-in
= 46,740 lb-in (RESISTING MOMENT) OR RIGHTING MOMENT

$FS = \frac{\Sigma M_R}{\Sigma M_D} = \frac{46,740 \text{ lb-in}}{13,099 \text{ lb-in}} = 3.57 > 2.0 \therefore$ OK

SLIDING STABILITY

$P_p = \frac{1}{2}\gamma H^2 K_p = \frac{1}{2}(120 \text{ lb/ft}^3)(1.92 \text{ ft})^2(1.667)$
= 367 lb/ft (NOTE: KEY HEIGHT INCLUDED)

WEIGHT ON BASE = $W_{RETWALL} + W_{SOIL} + W_{SW} + W_{SC}$
= 3221 lb/ft + 4548 lb/ft + 1785 lb/ft + 960 lb/ft
= 10,514 lb/ft (NOTE: KEY IS NOT ACCOUNTED FOR)

$\tan\phi_f$ = COEFFICIENT OF CONCRETE/SOIL FRICTION = 0.670

$V_f = P_f \tan\phi_f$ = 10,514 lb/ft × 0.670 = 7044 lb/ft

ΣP_R = 7044 lb/ft + 367 lb/ft = 7411 lb/ft
P_D = 2278 lb/ft + 810 lb/ft = 3088 lb/ft

$FS = \frac{\Sigma P_R}{P_D} = \frac{7290 \text{ lb/ft}}{3088 \text{ lb/ft}} = 2.36 > 1.50 \therefore$ OK

SLIDING RESISTANCE = 7411 lb/ft = 617.6 lb/in

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C1-14 OF_____

TITLE_____ BY K CHONG DATE 11/18/96

SOIL PRESSURE

TOTAL $W = \Sigma W = 10,514\ lb/ft$ (KEY NOT ACCOUNTED FOR)

$W = 876\ lb/in$

ECCENTRICITY:

$$\Sigma M_{TOE} = M_R - M_O + Wx$$

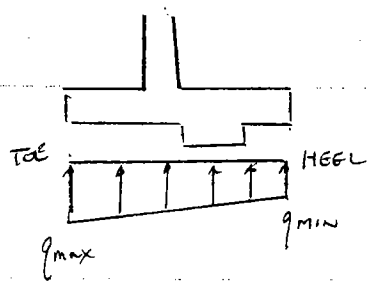
$$0 = 46704\ lb\text{-}in - 13,099\ lb\text{-}in + (876\ lb)x$$

$$x = 38.36\ in = 3.2\ ft$$

$$e = \frac{b}{2} - x = \left(\frac{7.5\ ft}{2} \times 12\ in/ft\right) - 38.36\ in$$

$$e = 6.64\ in < \frac{b}{6}\ (15\ in) \quad \therefore ok$$ IT'S IN FULL COMPRESSION

CHECK BEARING PRESSURE



$q_{all} = 20.83\ lb/in^2$

$$q = \frac{P}{L}\left(1 \pm \frac{6e}{L}\right)$$

$L = 7.5\ ft = 90\ in$

$P = W = 876\ lb/in$

$$q = \frac{876\ lb/in}{90\ in}\left(1 \pm \frac{6(6.64in)}{90\ in}\right)$$

AT THE TOE

$$q_{max} = 14.04\ lb/in^2 < 20.83 \quad \therefore ok$$

AT THE HEEL

$$q_{MIN} = 5.42\ lb/in^2$$

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET KCI-15 OF_____

TITLE_____ BY K CHONG DATE 11/18/96

VERIFICATION PROBLEM NO: 1 CHECK

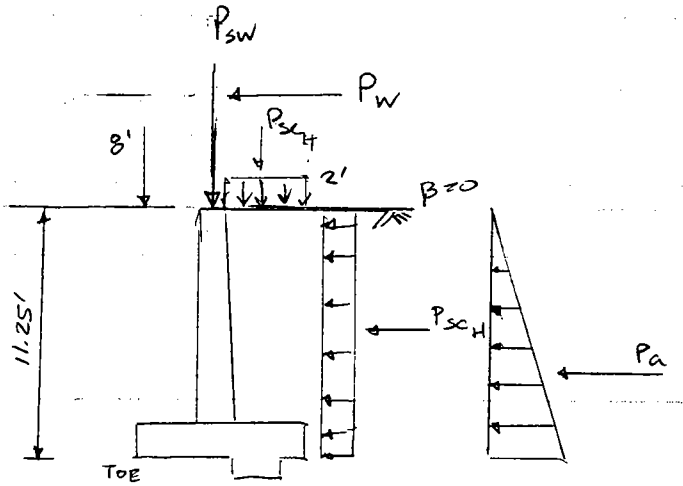
LOAD COMBINATION 2 : $0.75D + 0.75E + 0.75SC + 0.75W$

WIND LOAD = $30\ lb/ft^2 \times 16\ ft = 480\ lb/ft = 40\ lb/in$

FOR $b = 1\ in$

$P_W = 40\ lb$

LATERAL FORCE DISTRIBUTION



FOR $b = 1\ in$

$P_W = 40\ lb$

$P_a = 190\ lb$

$P_{SC_H} = 67.5\ lb$

$\Sigma F_x = 190\ lb + 67.5\ lb + 40\ lb = 297.5\ lb/in$

OVERTURNING STABILITY

$\Sigma M_R = 46,740\ lb\text{-}in$ (W/out KEY)

$\Sigma M_O = 13,099\ lb\text{-}in + (40\ lb \times 19.25ft \times 12\ in/ft)$

$= 22,339\ lb\text{-}in$

$FS = \frac{\Sigma M_R}{\Sigma M_O} = \frac{46,740\ lb\text{-}in}{22,339\ lb\text{-}in} = 2.09 > 1.50$ ∴ OK

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET C1-16 OF_____

TITLE_____ BY K. CHONG DATE 11/18/96

SLIDING STABILITY

$P_p = \frac{1}{2}\gamma H^2 K_p = \frac{1}{2}(120\ lb/ft^3)(1.92\ ft)^2(1.667) = 367\ lb/ft$
(KEY HEIGHT INCLUDED)

WEIGHT ON BASE = 10,514 lb/ft (KEY WEIGHT NOT ACCOUNTED)

$V_f = 10,514\ lb/ft \times 0.670 = 7044\ lb/ft$

ΣP_e = SLIDING RESISTANCE = 7044 lb/ft + 367 lb/ft = 7411 lb/ft
= 617.6 lb/in

$\Sigma P_D = 190\ lb/in + 67.5\ lb/in + 40\ lb/in$
$= 297.5\ lb/in$

$SF = \frac{\Sigma P_R}{\Sigma P_D} = \frac{617.6}{297.5} = 2.08 > 1.20 \therefore$ OK

SOIL PRESSURE

TOTAL W = 876 lb/in (KEY NOT ACCOUNTED FOR)

ECCENTRICITY

$\Sigma M_{TOE} = 46,740\ lb\text{-}in - 22,339\ lb\text{-}in + (876\ lb\text{-}in)x$

$x = 27.86\ in = 2.32\ ft$

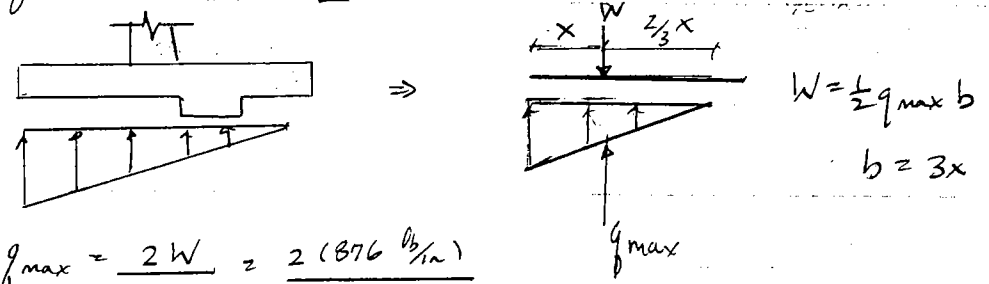
$e = \frac{b}{2} - x = \frac{90\ in}{2} - 27.86\ in = 17.14\ in$

$e = 17.14\ in \not< \frac{b}{6}(15\ in) \therefore$ FOOTING IS IN PARTIAL COMPRESSION

CHECK BEARING PRESSURE

$q_{all} = 1.33(20.83\ lb/in^2) = 27.70\ lb/in^2$

$q_{max} = \frac{P}{L}\left(1 + \frac{6e}{L}\right)$ ⇒ NO LONGER APPLIES



$q_{max} = \frac{2W}{b} = \frac{2(876\ lb/in)}{(3 \times 27.86 in)}$

$q_{max} = 20.96\ lb/in^2 < 27.70\ lb/in^2 \therefore$ OK

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET SC1-17 OF _____

TITLE _____ BY K. CHONG DATE 11/18/96

VERIFICATION PROBLEM NO: 1 CHECK

LOAD COMBINATION 3 : 0.75D + 0.75E + 0.75 EQD

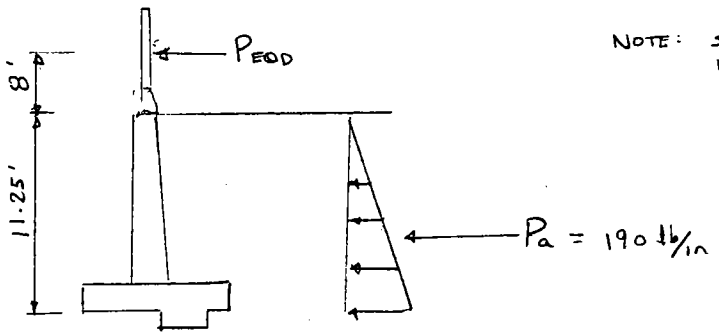
(NO SEISMIC EARTH LOAD)

* SEISMIC ACCEL
HORIZ: 0.3
VERT: 0.0

SEISMIC LOAD DUE TO SOUNDWALL

$P_{EQD} = 148.8\ lb/in \times 0.3 = 44.6\ lb/in$

LATERAL FORCE DISTRIBUTION



NOTE: SURCHARGE NOT INCLUDED FOR THIS CASE

$\Sigma F_x = 190\ lb/in + 44.6\ lb/in = 234.6\ lb/in$

OVERTURNING STABILITY

$\Sigma M_R = M_{RW+SOIL\ (W/OUT\ KEY)} + M_{SW}$
$= (37{,}154\ lb\text{-}in - 752\ lb\text{-}in) + 5058\ lb\text{-}in$
$= 41{,}460\ lb\text{-}in$

$\Sigma M_O = (190\ lb/in \times \frac{11.25\ ft}{3} \times 12\ in/ft) + (44.6\ lb/in \times 19.25\ ft \times 12\ in/ft)$
$= 8{,}550\ lb\text{-}in + 10{,}303\ lb\text{-}in$
$= 18{,}853\ lb\text{-}in$

$FS = \frac{\Sigma M_R}{\Sigma M_O} = \frac{41{,}460\ lb\text{-}in}{18{,}853\ lb\text{-}in} = 2.20 > 1.50 \therefore$ OK

SLIDING STABILITY

PASSIVE RESISTANCE : $P_p = \frac{1}{2} \gamma H^2 K_p = \frac{1}{2}(120\ lb/ft^3)(1.92\ ft)^2(1.667)$

Can use twice this value

$P_p = 367\ lb/ft$ (KEY HEIGHT ACCOUNTED)

WEIGHT ON BASE = $W_{RET\ WALL} + W_{SOIL} + W_{SW}$
$= 3221\ lb/ft + 4548\ lb/ft + 1785\ lb/ft$
$= 9554\ lb/ft$
$= 796.2\ lb/in$

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C1-18 OF _____

TITLE _____ BY K. CHONG DATE 11/18/96

SLIDING STABILITY

P_p = 367 lb/ft

W = 9554 lb/ft = 796.2 lb/in

$\tan\phi_f$ = 0.670 COEFFICIENT OF CONCRETE/SOIL FRICTION

$V_f = W \tan\phi_f$ = 9554 lb/ft (0.670) = 6401.2 lb/ft

ΣP_R = SLIDING RESISTANCE = 6401.2 lb/ft + 367 lb/ft x 2

= ~~6768.2~~ lb/ft 7135

= ~~564.0~~ lb/in 595

$\Sigma P_D = P_a + P_{EQD}$ = 234.6 lb/in

$$F.S. = \frac{\Sigma P_R}{\Sigma P_D} = \frac{\text{(595) } \cancel{564.0} \text{ lb/in}}{234.6 \text{ lb/in}} = \text{(2.54) } \cancel{2.40} > 1.20 \quad \therefore \text{ OK}$$

SOIL PRESSURE

TOTAL W = 796.2 lb/in

$\Sigma M_{TOE} = M_R - M_D + Wx = 0$

$0 = 41{,}460$ lbin $- 18{,}853$ lbin $+ (796.2$ lb/in$)\,x$

$x = 28.39$ in = 2.37 ft

$e = \frac{b}{2} - x = \frac{90 \text{ in}}{2} - 28.39 \text{ in}$

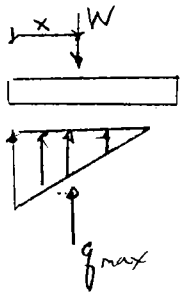
= 16.61 in

CHECK IF $e < \frac{b}{6} = 15$ in $\Rightarrow e \not< 15$ in

$\therefore$ IT'S IN PARTIAL COMPRESSION

$q_{all} = 1.33\,(20.83 \text{ lb/in}^2)$

$= 27.70 \text{ lb/in}^2$



NOTE: $q_{max} = \frac{P}{L}\left(1 + \frac{6e}{L}\right)$ IS NO LONGER VALID

$W = \frac{1}{2} q_{max}\, b$ WHICH $b = 3x$

$q_{max} = \frac{2W}{3x}$

$= \frac{2(796.2 \text{ lb/in})}{3(28.39 \text{ in})} = 18.70 \text{ lb/in}^2$

AT TOE: $q_{max} = 18.70 \text{ lb/in}^2 < 27.70 \text{ lb/in}^2 \quad \therefore$ OK

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C1-19 OF_____

TITLE_____ BY Rm DATE 7/29/99

MEMBER DESIGN

- Stem wall

Critical shear from load 1

$V = .3(.0694)(120)^2/2 + .3(1.667)(120) = 209.9$ lb/in

$d = 12 + 120 \tan 2.4^\circ - 2 - .625/2 = 14.72$ in

$V_c = 0.95\sqrt{3250}(14.72) = 797$ lb/in > 209.9 (OK)

Critical moment from load 2

$M = .3(.0694)(120)^3/6 + .3(1.667)(120)^3/2$
$+ 40 \times 120 + 3840 = 18237$ in-lbs

reduced $M = 0.75 \times 18237 = 13678$ in-lbs (Wind cond.)

use REBEAM with $H = 17.03$ $d = 14.72$
$A_S = .0517$ in^2/in

$f_s = 19420$ psi < 24000 (OK)
$f_c = 615$ psi < 1300 (OK)

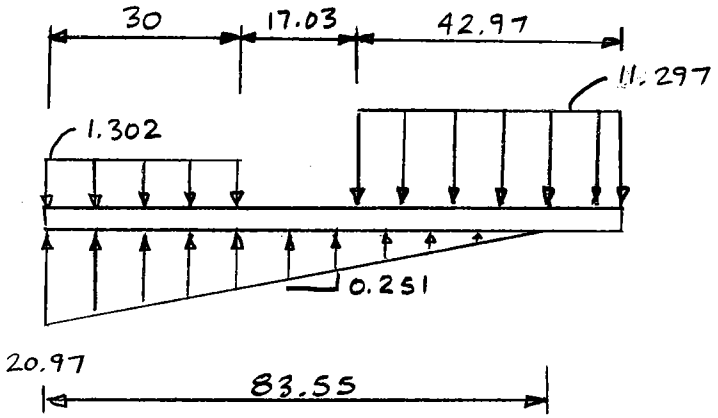
CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C1-20 OF_____

TITLE_____ BY RM DATE 7/29/99

- Footing

Shear and moment critical from load 2 (wmd)



@ Toe $V = (20.97 - 1.302)(30) - 0.251(30)^2/2 = 477$ lb/in

reduced $V = 0.75 \times 477 = 358$ lbs/in

$V_c = 0.95\sqrt{3250}(11.69) = 633 > 358$ (OK)

$M = 19.668(30)^2/2 - 0.251(30)^3/6 = 7721$ in-lbs

reduced $M = 0.75 \times 7721 = 5791$ in-lbs

$f_s = 10441$ psi < 24000 (OK)

$f_c = 377$ psi < 1300 (OK)

↑ Stresses from REBEAM

@ Heel $V = 11.297(42.97) - 0.251(36.52)^2/2 = 318$ lb/in

reduced $V = 0.75 \times 318 = 239$ lbs/in

$V_c = 0.95\sqrt{3250}(12.69) = 687 > 239$ (OK)

$M = 11.297(42.97)^2/2 - 0.251(36.52)^3/6 = 8392$ in-lbs

reduced $M = 0.75 \times 8392 = 6294$ in-lbs

$f_s = 10421$ psi < 24000 (OK)

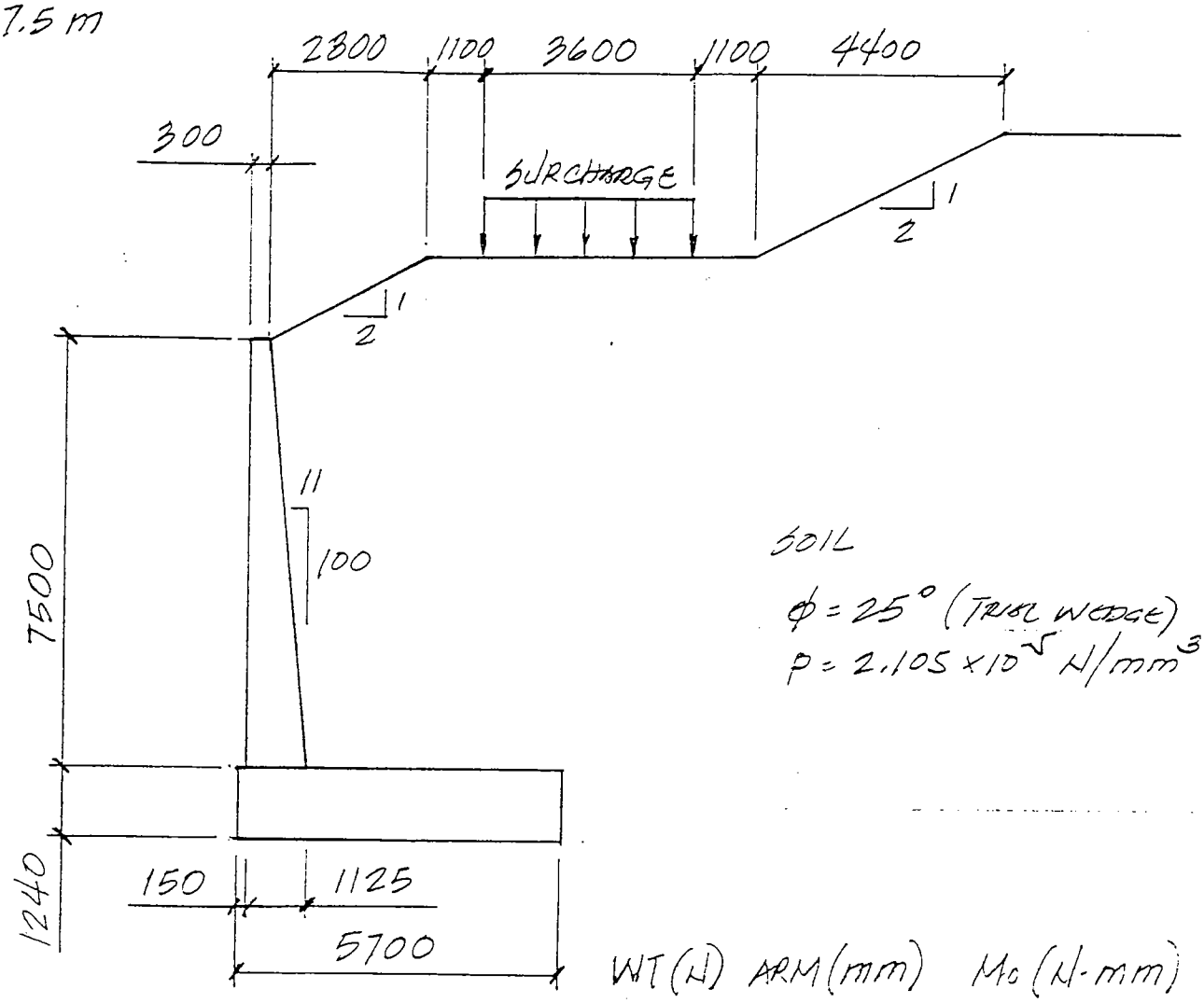
$f_c = 359$ psi < 1300 (OK)

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C2-1 OF _____

TITLE SANTA PAULA CREEK BY JQ DATE _____

H = 7.5 m



SOIL

$\phi = 25°$ (TRIAL WEDGE)

$\rho = 2.105 \times 10^{-5}$ N/mm^3

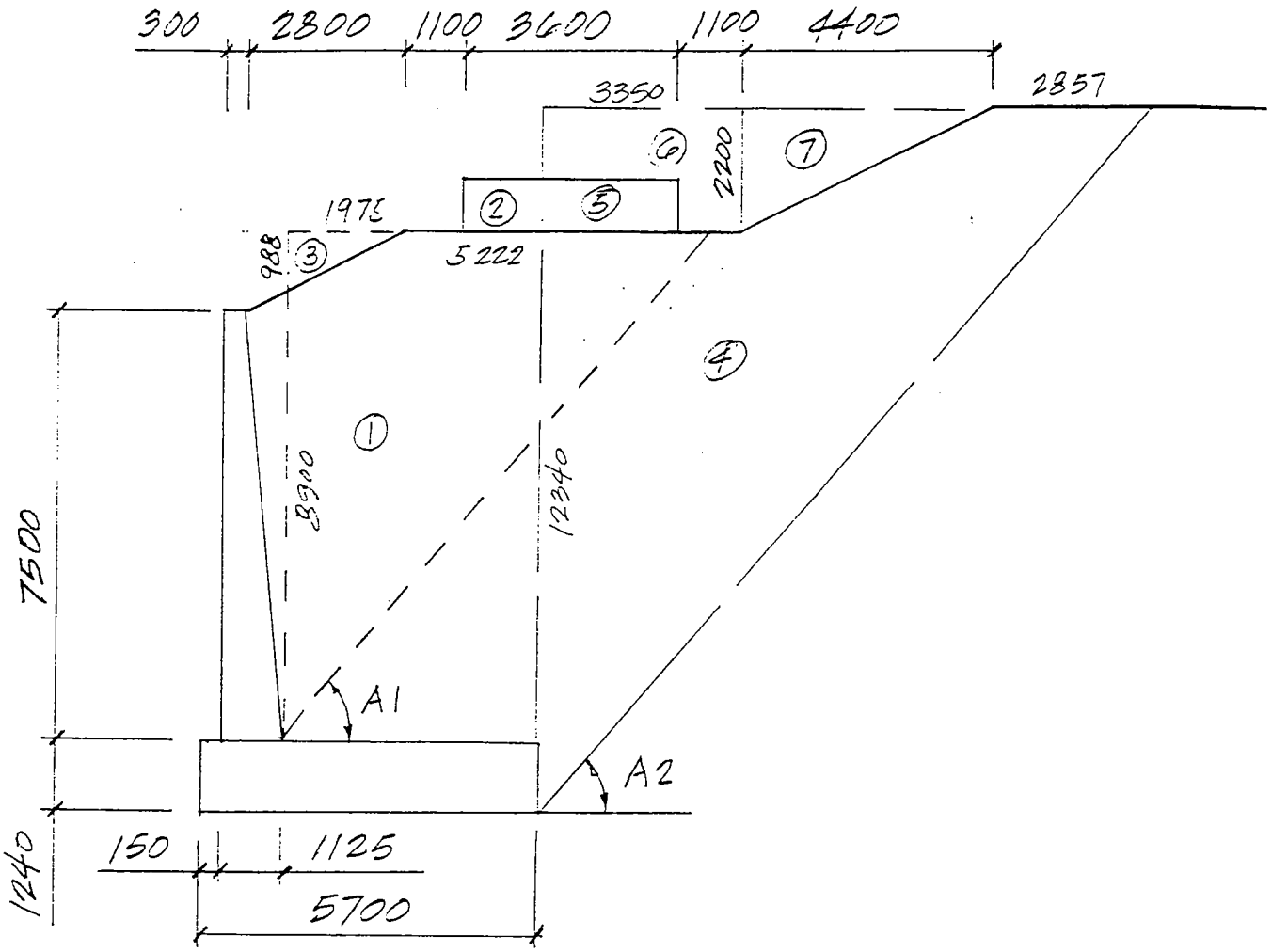
	WT (N)	ARM (mm)	M_o (N-mm)
$300 \times 7500 \times 2.36 \times 10^{-5}$	53.10	300	15 930
$825 \times 7500/2 \times 2.36 \times 10^{-5}$	73.01	725	52 934
$5700 \times 1240 \times 2.36 \times 10^{-5}$	166.80	2850	475 394
$825 \times 3750 \times 2.105 \times 10^{-5}$	65.12	1000	65 120
$2800 \times 1400/2 \times 2.105 \times 10^{-5}$	41.26	2317	95 595
$2450 \times 1400 \times 2.105 \times 10^{-5}$	72.20	4475	323 102
$4425 \times 7500 \times 2.105 \times 10^{-5}$	698.60	3488	2436 357
$1350 \times 610 \times 2.105 \times 10^{-5}$	17.33	5025	87 107
TOTAL	1187.42		3.551 539

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET C4-2 OF_____

TITLE SANTA PAULA CREEK BY JQ DATE_____

H = 7.5 m (CONT)



ANGLES OF FAILURE PLANE:

A1 = 51.04° CRITICAL WEDGE BY TRIAL AND ERROR

A2 = 49.32° CRITICAL WEDGE BY TRIAL AND ERROR

$W1 = W1 + W2 - W3$

$W2 = W4 + W5 - W6 - W7$

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C4-3 OF _____

TITLE SONTA PAULA CREEK BY JR DATE _____

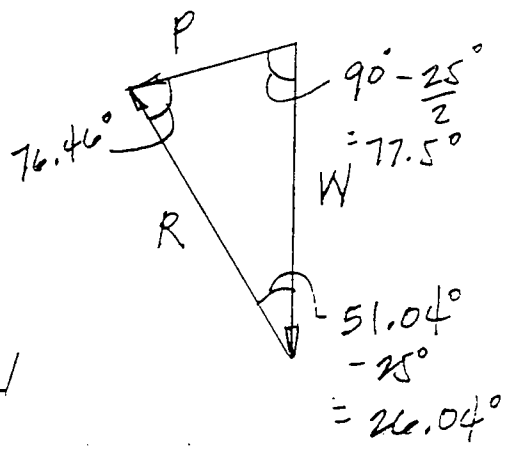
H = 7.5 m (CONT)

WALL DESIGN:

		WT (N)
1	$8900 \times 7197/2 \times 2.105 \times 10^{-5}$	674.16
2	$610 \times 3600 \times 2.105 \times 10^{-5}$ (SC)	46.22
(-)3	$988 \times 1975/2 \times 2.105 \times 10^{-5}$	- 20.54
W1	(W/O SURCHARGE)	653.62
	(W/ SURCHARGE)	699.84

$$P_E = \frac{653.62 \sin 26.04^\circ}{\sin 76.46^\circ} = 295.14 \text{ N}$$

$$P_{Eh} = 295.14 \cos 12.5^\circ = 288.14 \text{ N}$$



$$P_T = \frac{699.84 \sin 26.04^\circ}{\sin 76.46^\circ} = 316.01 \text{ N}$$

$$P_{Th} = 316.01 \cos 12.5^\circ = 308.52 \text{ N}$$

$$P_{SC} = 308.52 - 288.14 = 20.38 \text{ N}$$

LOCATION OF (E+SC) FORCE

$$Y = \frac{288.14 (7912/3) + 20.38 (8900/2)}{308.52}$$

$$= 2757 \text{ mm}$$

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET C4-4 OF_____

TITLE SANTA PAULA CREEK BY JQ DATE_____

H = 7.5 m (CONT)

$V_u = 2.21 \times 308.52 = 681.83$ N

32 @ 140 $A_s = 1783$ sq-mm

$d = 1125 - 32/2 - 100 = 1009$ mm

$\phi V_c = 0.85 \times 2 \times \sqrt{25} \times 1/12 \times 1009$

$= 714.71$ N > 681.83 N ok

$M_d = 681.83 \times 2757 = 1879805$ N-mm

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{1783 \times 420}{0.85 \times 25 \times 304.8} = 116$ mm

$\phi M_n = 0.9(1783)(420)(1009 - 116/2)/304.8$

$= 2102900$ N-mm > 1879805 N-mm ok

$1.2 M_{cr} = 885938$ N-mm < 2102900 N-mm

CRACKING DOESN'T CONTROL

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET C2-5 OF_____

TITLE SANTA PAULA CREEK BY JQ DATE_____

H = 7.5 m (CONT)

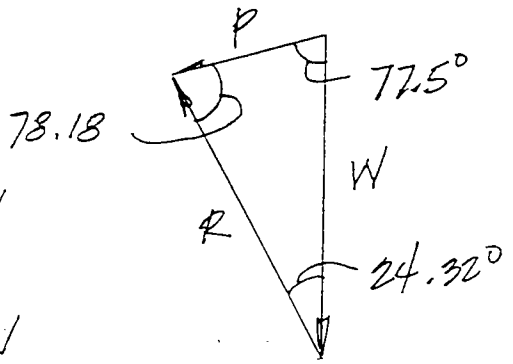
FOOTING DESIGN:

		WT (N)
4	$12340 \times 10607/2 \times 2.105 \times 10^{-5}$	= 1377.62
5	$610 \times 2250 \times 2.105 \times 10^{-5}$	= 28.89
(-) 6	$3350 \times 2200 \times 2.105 \times 10^{-5}$	= -155.14
(-) 7	$2200 \times 4400/2 \times 2.105 \times 10^{-5}$	= -101.38
	W2	1149.49

$Y = (1240 + 7500 + 1400)/3$

$= 3380$ mm

$P = \dfrac{1149.49 \sin 24.32^\circ}{\sin 78.18^\circ} = 483.65$



$P_V = 483.65 \sin 12.5^\circ = 104.68$ N

$P_h = 483.65 \cos 12.5^\circ = 472.19$ N

OVERTURNING:

$M_{RT} = 3551539 + 104.68 \times 5700 = 4148215$ N-mm

$M_{OT} = 472.19\,(3380) = 1596000$ N-mm

$FS = \dfrac{4148215}{1596000} = 2.60$ (ok)

Form QA-66 (1) (8-96)

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C2-6 OF _____

TITLE SANTA PAULA CREEK BY JQ DATE _____

H = 7.5 m (CONT)

SOIL PRESSURE :

$$e = \frac{5700}{2} - \frac{(4148215 - 1596000)}{1187.42 + 104.68} = 875 < \frac{5700}{6}$$ ok

$$q_{TOE} = \frac{1292.10}{5700}\left(1 + \frac{6 \times 875}{5700}\right) = 0.436 < 0.48$$ ok

$$q_{HEEL} = \frac{1292.10}{5700}\left(1 - \frac{6 \times 875}{5700}\right) = 0.018$$

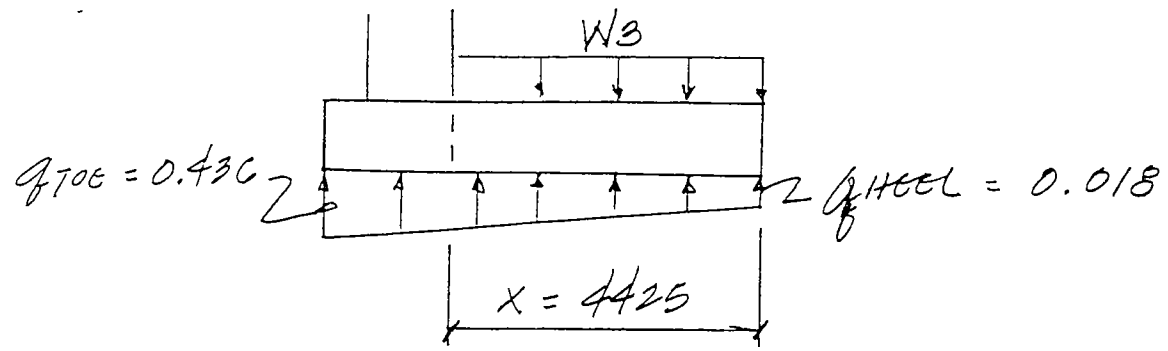
SLIDING :

$$P_{RES} = 1292.10 \times 0.55 = 710.66\ N$$

$$P_{SL} = 472.19\ N$$

$$FS = \frac{710.66}{472.19} = 1.51 > 1.50$$ ok

HEEL REINFORCING :



CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C2-7 OF_____

TITLE SANTA PAULA CREEK BY JQ DATE_____

H = 7.5 m (CONT)

$$W3 = 1240 \times 2.56 \times 10^{-6} + 8750 \times 2.105 \times 10^{-5}$$

$$= 0.213$$

$$q = 0.213 - 0.018 - \left(\frac{0.436 - 0.018}{5700}\right) X$$

$$= 0.195 - \left(7.3 \times 10^{-5}\right) X$$

$$Vd = 2.21 \left[0.195(4425) - 7.3 \times 10^{-5}(4425)^2/2 + 104.68\right]$$

$$= 551.61$$

36 @ 140 ; As = 2190 SQ-mm

$$d = 1240 - 36/2 - 100 = 1122 \text{ mm}$$

$$\phi Vc = 0.85 \times 2 \times \sqrt{25} \times 1/12 \times 1122 = 794.75 N > 551.61$$ ok

$$Md = 2.21 \left[0.195(4425)^2/2 - 7.3 \times 10^{-5}(4425)^3/6 + 104.68(4425)\right]$$

$$= 2.902500 \text{ N-mm}$$

$$a = \frac{As\, fy}{0.85 f'c\, b} = \frac{2190 \times 420}{0.85 \times 25 \times 304.8} = 142 \text{ mm}$$

$$\phi Mn = 0.9(2190)(420)(1122 - 142/2)/304.8$$

$$= 2854500 \text{ N-mm}$$

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C2-8 OF_____

TITLE SANTA PAULA CREEK BY JQ DATE_____

H= 7.5 m (CONT)

ϕM_n = 2854500 N-mm ~ 2902500 N-mm OK

1.2 M_{cr} = 1076320 N-mm < 2854500 N-mm

CRACKING DOESN'T CONTROL

RETAIN PROGRAM OUTPUT

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   R E T A I N                   *
*                                                         *
*                 INPUT DATA ECHO                         *
*                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
(Version  1.42)                5/02/2007,  5:08:13

Input file  = V2.IN
Output file = V2_1.42.out

P R O G R A M   O P T I O N S
=====================================================

PROGRAM UNITS      =  2 (SI: millimeters/newtons/degrees)
ANALYSIS MODE      =  2 (Review)
CONCRETE DESIGN    =  1 (Ultimate strength)
SOIL CONFIGURATION =  2 (Irregular)
FOUNDATION TYPE    =  1 (Spread footing)

M A T E R I A L   P R O P E R T I E S
=====================================================

CONCRETE PROPERTIES:

     Concrete unit weight          = 0.2360E-04
     Concrete compressive strength =  25.00
     Reinforcing steel strength    =  420.0

SOIL PROPERTIES:

     Soil unit weight              = 0.2105E-04
     Soil friction angle           =  25.00
     Soil base cohesion            =  0.000

S O I L   P A R A M E T E R S
=====================================================

LATERAL PRESSURE COEFFICIENT:

     Regular loads =  0.300  @ Y =  0.333H
     Seismic loads =  0.000  @ Y =  0.500H

PASSIVE PRESSURE COEFFICIENT:

     Regular loads =  0.000
     Seismic loads =  0.000
```

```
SOIL/SOIL FRICTION COEFFICIENT:

     Regular loads =  0.220
     Wind loads    =  0.220
     Seismic loads =  0.220

SOIL/SOIL FRICTION OPTION:

     Option        =  1 (Use Pa vert component)

L O A D S
=====================================================

LOADS AT TOP OF WALL:

     Dead load      =  0.000      @ X =  0.000
     Live load      =  0.000      @ X =  0.000
     Wind shear     =  0.000
     Wind moment    =  0.000
     Seismic shear  =  0.000
     Seismic moment =  0.000

SEISMIC ACCELERATION:

     Horizontal     =  0.000
     Vertical       =  0.000

LOAD COMBINATIONS:

      2.210D + 0.000L + 2.210E + 2.210SC + 0.000W + 0.000EQ

S O I L   C O N F I G U R A T I O N
=====================================================

Design height           =  7500.
Height of soil over toe =  0.000

IRREGULAR BACKFILL SEGMENTS:

NO       LENGTH      ANGLE
---------------------------

 1       3130.       26.57
 2       5800.       0.000
 3       4919.       26.57
 4       5000.       0.000
```

```
IRREGULAR SURCHARGE LOAD:

NO    LOAD      XBEG      YBEG      XEND      YEND
-------------------------------------------------

 1    46.20     3900.     1400.     7500.     1400.

W A L L   C O N F I G U R A T I O N
=================================================

Minimum wall thickness    =  300.0
Wall batter               =  6.277
Footing thickness         =  1240.
Key depth                 =  0.000
Toe width                 =  150.0
Footing width             =  5700.

R E B A R   C O N F I G U R A T I O N
=====================================================

REINFORCING STEEL INFORMATION:

     Bar diameter           =  36.00
     Ratio of balanced reinf = 0.2500

CONCRETE COVER:

     At wall backface       =  100.0
     At footing top         =  100.0
     At footing bottom      =  100.0

REINFORCING STEEL AREA:

     At wall backface       =  5.850
     At footing top         =  7.186
     At footing bottom      =  5.850

S P R E A D   F O O T I N G
=====================================================

ALLOWABLE SOIL BEARING PRESSURE:

     Regular loads = 0.4800
     Wind loads    = 0.4800
     Seismic loads = 0.4800

CONCRETE/SOIL FRICTION COEFFICIENT:

     Regular loads =  0.550
     Wind loads    =  0.550
     Seismic loads =  0.550
```

```
OVERTURNING SAFETY FACTORS:

     Regular loads =  1.000
     Wind loads    =  1.000
     Seismic loads =  1.000

SLIDING SAFETY FACTORS:

     Regular loads =  1.500
     Wind loads    =  1.200
     Seismic loads =  1.200


* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                       *
*           P R O G R A M   R E T A I N                 *
*                                                       *
*                    OUTPUT DATA                        *
*                                                       *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *

W A L L   D E S I G N
=====================================================

TRIAL WEDGE ANALYSIS:

  EARTH FORCE   =  296.2
    Angle       =  12.41
    Xapp        =  1275.
    Yapp        =  2803.
  Failure angle =  53.33
  Soil wedge wt =  600.2
    Xcg         =  3541.
    Ycg         =  5846.
  Ka (equiv)    = 0.4495
  Height        =  7913.

  E + SUR FORCE =  318.7
    Angle       =  12.41
    Xapp        =  1275.
    Yapp        =  2773.
  Failure angle =  53.33
  Soil wedge wt =  645.8
    Xcg         =  3723.
    Ycg         =  6062.
  Ka (equiv)    = 0.4836
  Height        =  7913.

LOAD COMBINATION   1:

  Shear  =  687.8
  Moment = 0.1907E+07
```

```
     Shear capacity  =  713.3     > Design shear  =  687.8     OKAY
     Moment capacity = 0.2098E+07 > Design moment = 0.1907E+07 OKAY
     Steel area      =  5.850     < Max stl area  =  6.368     OKAY

W A L L   L O A D   D I S T R I B U T I O N
==================================================

     DEPTH     SHEAR    MOMENT     THICK   AS REQD

      600.       15.     5726.   365.733     0.061
     1200.       38.    26574.   431.465     0.226
     1800.       67.    68049.   497.198     0.481
     2400.      103.   135656.   562.931     0.822
     3000.      146.   234899.   628.664     1.247
     3600.      196.   301366.   694.396     1.418
     4200.      253.   412735.   760.129     1.748
     4800.      316.   583121.   825.862     2.250
     5400.      387.   793748.   891.595     2.816
     6000.      464.  1048746.   957.327     3.446
     6600.      549.  1352242.  1023.060     4.140
     7200.      640.  1708365.  1088.793     4.901

W E I G H T   A N D   R I G H T I N G   M O M E N T
==================================================

DEAD LOAD       =  1170.
RIGHTING MOMENT = 0.3463E+07

LIVE LOAD       =  0.000
RIGHTING MOMENT =  0.000

SURCHARGE LOAD  =  17.33
RIGHTING MOMENT = 0.8706E+05

E X T E R N A L   S T A B I L I T Y   A N A L Y S I S
==================================================

TRIAL WEDGE ANALYSIS:

  EARTH FORCE   =  471.8
    Angle       =  12.41
    Xapp        =  5700.
    Yapp        =  3377.
  Failure angle =  48.75
  Soil wedge wt =  1149.
    Xcg         =  9464.
    Ycg         =  7521.
  Ka (equiv)    = 0.4360
  Height        = 0.1014E+05
```

```
    E + SUR FORCE =  483.8
      Angle       =  12.41
      Xapp        =  5700.
      Yapp        =  3377.
    Failure angle =  49.32
    Soil wedge wt =  1149.
      Xcg         =  9315.
      Ycg         =  7570.
    Ka (equiv)    = 0.4471
    Height        = 0.1014E+05

  LOAD COMBINATION   1:

    Lateral force      =  472.5
    Overturning moment = 0.1596E+07
    Total weight       =  1291.
    Righting moment    = 0.4143E+07
    Sliding resistance =  710.3

    Sliding SF         =   1.50     >   1.50     OKAY
    Overturning SF     =   2.60     >   1.00     OKAY

    SOIL PRESSURE:

      Eccentricity  =  877.5
      Toe pressure  = 0.4358
      Heel pressure = 0.1729E-01

      Max pressure  = 0.4358     < 0.4800     OKAY

  F O O T I N G   D E S I G N
  ==================================================

  LOAD COMBINATION   1:

    Lateral force      =  1044.
    Overturning moment = 0.3526E+07
    Weight             =  2854.
    Righting moment    = 0.9156E+07

    SOIL PRESSURE:

      Eccentricity  =  877.5
      Toe pressure  = 0.9632
      Heel pressure = 0.3822E-01

    FOOTING TOE:

      Shear  =  133.0
      Moment = 0.1002E+05
```

```
  Shear capacity  =  794.8     > Design shear  =  133.0     OKAY
  Moment capacity = 0.2353E+07 > Design moment = 0.1336E+05 OKAY
  Steel area      =  5.850     < Max stl area  =  7.096     OKAY

FOOTING HEEL:

  Shear  =  552.8
  Moment = 0.2951E+07

  Shear capacity  =  794.8     > Design shear  =  552.8     OKAY
  Moment capacity = 0.2854E+07 < Design moment = 0.2951E+07 NG ***
  Steel area      =  7.186     > Max stl area  =  7.096     NG ***
```

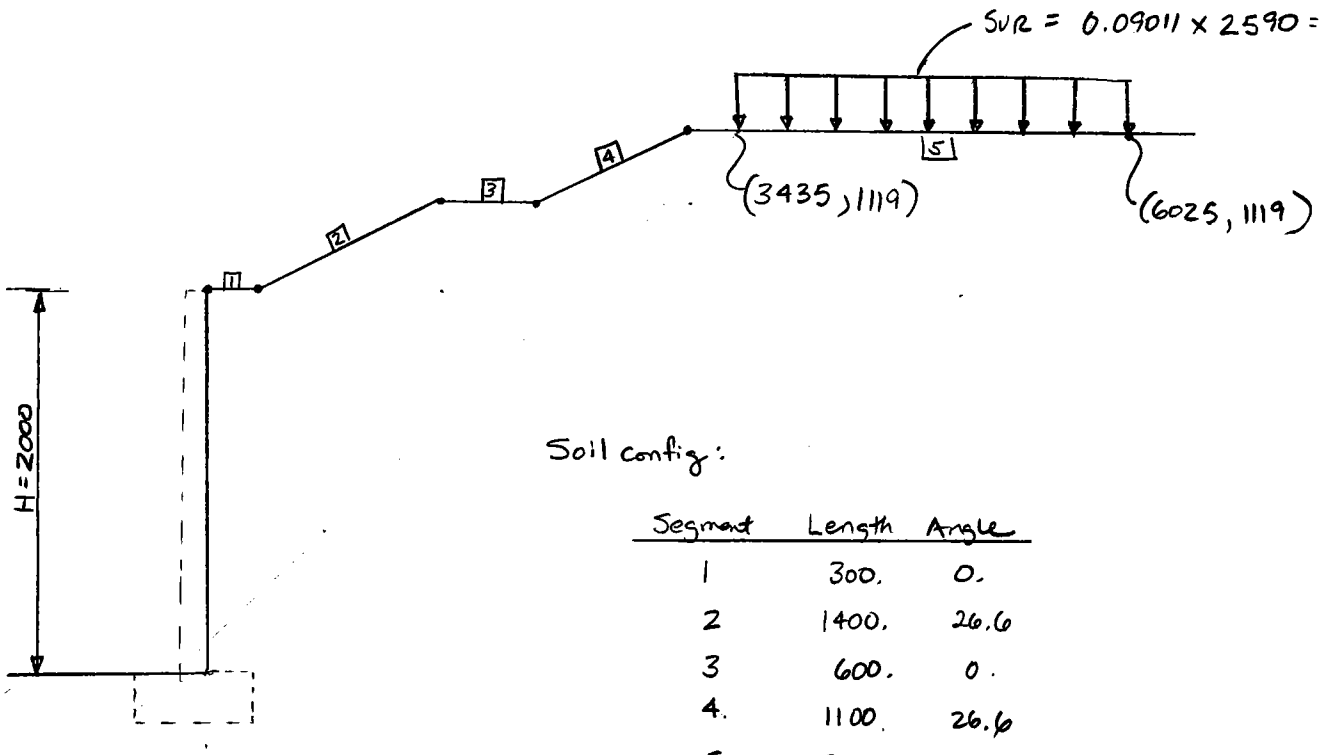
CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-1 OF_____

TITLE_____ BY BM DATE 10/12/96

Verification Problem No 3

Design wall for irregular backfill & RR surcharge



Soil config:

Segment	Length	Angle
1	300.	0.
2	1400.	26.6
3	600.	0.
4.	1100.	26.6
5.	5000.	0.

$\phi = 34°$

$CS = 0.4$

$A_h = 0.2$

RETAIN PROGRAM OUTPUT

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   R E T A I N                   *
*                                                         *
*                 INPUT DATA ECHO                         *
*                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
(Version  1.42)                5/02/2007,  5:08:28

Input file  = V3.IN
Output file = V3_1.42.out

P R O G R A M   O P T I O N S
=====================================================

PROGRAM UNITS      =  2 (SI: millimeters/newtons/degrees)
ANALYSIS MODE      =  1 (Design)
CONCRETE DESIGN    =  1 (Ultimate strength)
SOIL CONFIGURATION =  2 (Irregular)
FOUNDATION TYPE    =  1 (Spread footing)
                        <Optimized by volume>

M A T E R I A L   P R O P E R T I E S
=====================================================

CONCRETE PROPERTIES:

     Concrete unit weight          = 0.2360E-04
     Concrete compressive strength =  25.00
     Reinforcing steel strength    =  420.0

SOIL PROPERTIES:

     Soil unit weight              = 0.1900E-04
     Soil friction angle           =  34.00
     Soil base cohesion            =  0.000

S O I L   P A R A M E T E R S
=====================================================

LATERAL PRESSURE COEFFICIENT:

     Regular loads =  0.300  @ Y =  0.333H
     Seismic loads =  0.000  @ Y =  0.500H

PASSIVE PRESSURE COEFFICIENT:

     Regular loads =  1.667
     Seismic loads =  3.333
```

```
SOIL/SOIL FRICTION COEFFICIENT:

     Regular loads =  0.000
     Wind loads    =  0.000
     Seismic loads =  0.330

SOIL/SOIL FRICTION OPTION:

     Option        =  0 (No Pa vert component)

L O A D S
=====================================================

LOADS AT TOP OF WALL:

     Dead load      =  0.000      @ X =  0.000
     Live load      =  0.000      @ X =  0.000
     Wind shear     =  0.000
     Wind moment    =  0.000
     Seismic shear  =  0.000
     Seismic moment =  0.000

SEISMIC ACCELERATION:

     Horizontal     = 0.2000
     Vertical       =  0.000

LOAD COMBINATIONS:

      1.300D + 0.000L + 1.700E + 1.700SC + 0.000W + 0.000EQ
      1.300D + 0.000L + 0.000E + 0.000SC + 0.000W + 1.300EQ

S O I L   C O N F I G U R A T I O N
=====================================================

Design height           =  2000.
Height of soil over toe =  300.0

IRREGULAR BACKFILL SEGMENTS:

NO       LENGTH      ANGLE
---------------------------

 1       300.0       0.000
 2       1400.       26.60
 3       600.0       0.000
 4       1100.       26.60
 5       5000.       0.000

IRREGULAR SURCHARGE LOAD:
```

```
NO    LOAD      XBEG      YBEG      XEND      YEND
-------------------------------------------------

 1    233.0     3435.     1119.     6025.     1119.

W A L L   C O N F I G U R A T I O N
=================================================

Minimum wall thickness    =  300.0
Minimum wall batter       =  2.400
Minimum footing thickness =  400.0
Maximum key depth         =  300.0
Maximum toe width         =  2500.
Maximum heel width        =  2500.
Minimum toe width         =  0.000

R E B A R   C O N F I G U R A T I O N
=====================================================

REINFORCING STEEL INFORMATION:

     Bar diameter            =  30.00
     Ratio of balanced reinf = 0.5000

CONCRETE COVER:

     At wall backface        =  50.00
     At footing top          =  50.00
     At footing bottom       =  75.00

S P R E A D   F O O T I N G
=====================================================

ALLOWABLE SOIL BEARING PRESSURE:

     Regular loads = 0.1920
     Wind loads    = 0.2550
     Seismic loads = 0.2550

CONCRETE/SOIL FRICTION COEFFICIENT:

     Regular loads =  0.400
     Wind loads    =  0.400
     Seismic loads =  0.400

OVERTURNING SAFETY FACTORS:

     Regular loads =  2.000
     Wind loads    =  1.500
     Seismic loads =  1.500
```

```
SLIDING SAFETY FACTORS:

     Regular loads =  1.500
     Wind loads    =  1.200
     Seismic loads =  1.200


* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                       *
*           P R O G R A M   R E T A I N                 *
*                                                       *
*                    OUTPUT DATA                        *
*                                                       *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *

W A L L   D E S I G N
=====================================================

TRIAL WEDGE ANALYSIS:

  EARTH FORCE   =  13.82
    Angle       =  0.000
    Xapp        =  383.8
    Yapp        =  666.0
  Failure angle =  56.77
  Soil wedge wt =  32.92
    Xcg         =  981.4
    Ycg         =  1557.
  Ka (equiv)    = 0.3636
  Height        =  2000.

  SEISMIC FORCE =  23.66
    Angle       =  18.26
    Xapp        =  383.8
    Yapp        =  1000.
  Failure angle =  40.15
  Soil wedge wt =  75.59
    Xcg         =  1694.
    Ycg         =  1782.
  Kaeq (equiv)  = 0.6226
  Height        =  2000.

LOAD COMBINATION   1:

  Shear  =  23.49
  Moment = 0.1564E+05

LOAD COMBINATION   2:

  Shear  =  29.21
  Moment = 0.2921E+05
```

```
MAXIMUM LOADS:

  Shear  =  29.21
  Moment = 0.2921E+05

    Design moment   = 0.3894E+05
    Wall thickness  =  383.8
    Steel area      = 0.3265
    Max steel area  =  4.032

C O N V E R G E D   D E S I G N
======================================================

WALL BATTER                =    2.399
FOOTING THICKNESS          =    400.0
TOE WIDTH                  =    1200.
FOOTING WIDTH              =    1650.
KEY DEPTH                  =    300.0

STEEL AREA AT WALL         =   0.3265
STEEL AREA AT FOOTING TOP  =   0.1097E-01
STEEL AREA AT FOOTING BOT  =   0.4243

W E I G H T   A N D   R I G H T I N G   M O M E N T
======================================================

DEAD LOAD       =  42.67
RIGHTING MOMENT = 0.4565E+05

LIVE LOAD       =  0.000
RIGHTING MOMENT =  0.000

SURCHARGE LOAD  =  0.000
RIGHTING MOMENT =  0.000

E X T E R N A L   S T A B I L I T Y   A N A L Y S I S
======================================================

TRIAL WEDGE ANALYSIS:

  EARTH FORCE   =  20.10
    Angle       =  0.000
    Xapp        =  1650.
    Yapp        =  799.2
  Failure angle =  57.91
  Soil wedge wt =  45.33
    Xcg         =  2316.
    Ycg         =  1860.
  Ka (equiv)    = 0.3673
  Height        =  2400.
```

```
   E + SUR FORCE =  21.79
     Angle       =  0.000
     Xapp        =  1650.
     Yapp        =  799.2
   Failure angle =  43.02
   Soil wedge wt =  137.3
     Xcg         =  3683.
     Ycg         =  2529.
   Ka (equiv)    = 0.3981
   Height        =  2400.

   SEISMIC FORCE =  33.62
     Angle       =  18.26
     Xapp        =  1650.
     Yapp        =  1200.
   Failure angle =  41.87
   Soil wedge wt =  98.70
     Xcg         =  3048.
     Ycg         =  2081.
   Kaeq (equiv)  = 0.6144
   Height        =  2400.

 LOAD COMBINATION   1:

   Lateral force      =  21.79
   Overturning moment = 0.1741E+05
   Total weight       =  42.67
   Righting moment    = 0.4565E+05
   Sliding resistance =  32.90

   Sliding SF         =   1.51     >   1.50     OKAY
   Overturning SF     =   2.62     >   2.00     OKAY

   SOIL PRESSURE:

     Eccentricity  =  163.2
     Toe pressure  = 0.4121E-01
     Heel pressure = 0.1051E-01

     Max pressure  = 0.4121E-01 < 0.1920     OKAY

 LOAD COMBINATION   2:

   Lateral force      =  31.93
   Overturning moment = 0.3831E+05
   Total weight       =  53.21
   Righting moment    = 0.6303E+05
   Sliding weight     =  42.67
   Sliding resistance =  48.73

   Sliding SF         =   1.53     >   1.20     OKAY
   Overturning SF     =   1.65     >   1.50     OKAY
```

```
   SOIL PRESSURE:

     Eccentricity  =  360.4
     Toe pressure  = 0.7635E-01
     Footing is in partial compression

     Max pressure  = 0.7635E-01 < 0.2550     OKAY

F O O T I N G   D E S I G N
==================================================

LOAD COMBINATION   1:

   Lateral force      =  37.04
   Overturning moment = 0.2960E+05
   Weight             =  55.47
   Righting moment    = 0.5934E+05

   SOIL PRESSURE:

     Eccentricity  =  288.8
     Toe pressure  = 0.6897E-01
     Footing is in partial compression

   FOOTING TOE:

     Shear  =  28.27
     Moment = 0.2314E+05

     Shear capacity  =  219.6     > Design shear  =  28.27     OKAY
     Moment capacity = 0.4904E+05 > Design moment = 0.3085E+05 OKAY
     Steel area      = 0.4243     < Max stl area  =  3.921     OKAY

   FOOTING HEEL:

     Shear  =  4.082
     Moment =  134.2

     Shear capacity  =  237.3     > Design shear  =  4.082     OKAY
     Moment capacity =  1389.     > Design moment =  178.9     OKAY
     Steel area      = 0.1097E-01 < Max stl area  =  4.237     OKAY

LOAD COMBINATION   2:

   Lateral force      =  41.51
   Overturning moment = 0.4981E+05
   Weight             =  69.17
   Righting moment    = 0.8194E+05
```

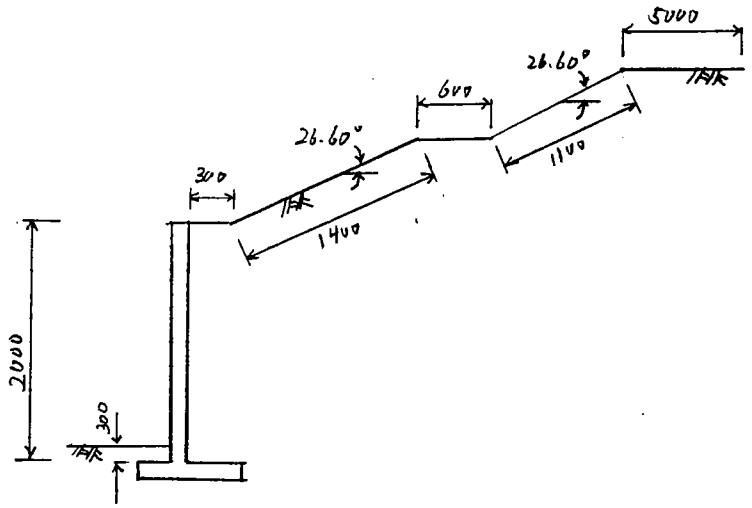
```
SOIL PRESSURE:

  Eccentricity  =  360.4
  Toe pressure  = 0.9925E-01
  Footing is in partial compression

FOOTING TOE:

  Shear  =  44.21
  Moment = 0.3678E+05

  Shear capacity  =  219.6     > Design shear  =  44.21     OKAY
  Moment capacity = 0.4904E+05 > Design moment = 0.4904E+05 OKAY
  Steel area      = 0.4243     < Max stl area  =  3.921     OKAY

FOOTING HEEL:

  Shear  =  17.79
  Moment =  1041.

  Shear capacity  =  237.3     > Design shear  =  17.79     OKAY
  Moment capacity =  1389.     > Design moment =  1389.     OKAY
  Steel area      = 0.1097E-01 < Max stl area  =  4.237     OKAY
```

CHECKED _____ DATE _____ JOB NO. _____

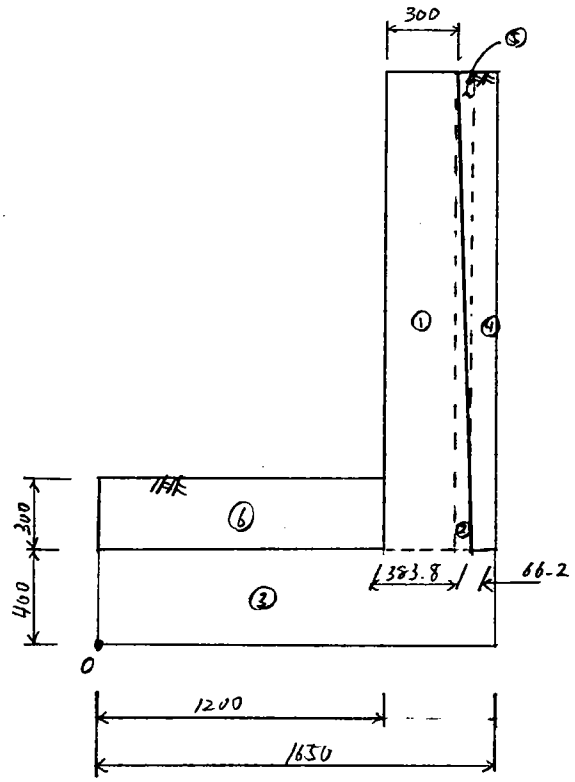
APPROVED _____ DATE _____ SHEET C3-10 OF _____

TITLE Verification of New RETAIN for Irregular Backfill BY Y. Matsuo DATE 11/22/96

Soil Configuration



Wall Configuration (Converged Design)



section	Area	wt	Dist	Mo
①	600000	14.16	1350	19116
②	83800	1.98	1527.93	3025.30
③	660000	15.58	825	12853.50
④	132400	2.52	1616.9	4074.59
⑤	83800	1.59	1555.87	2473.83
⑥	360000	6.84	600	4104.
		42.67 N		45647.22

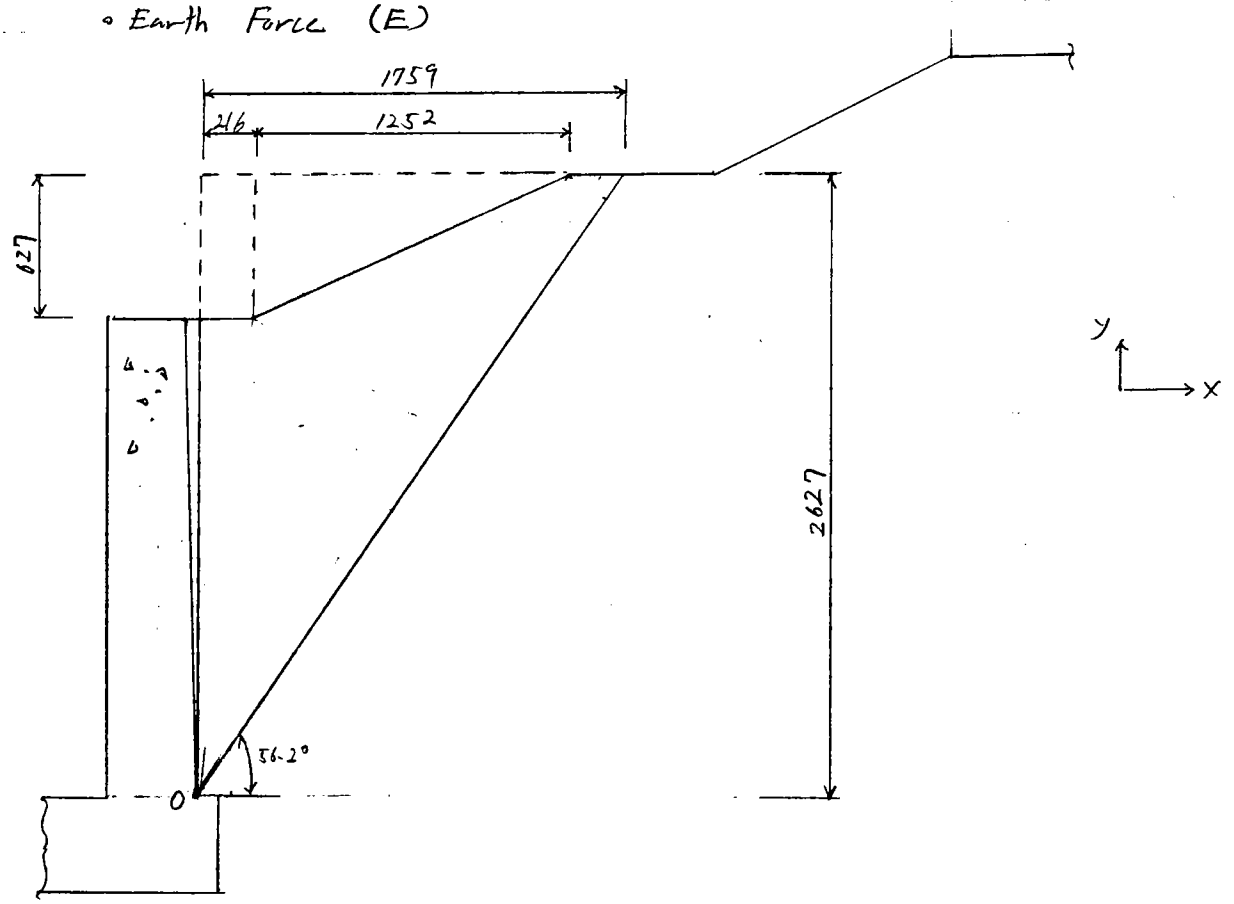
CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-11 OF _____

TITLE _____ BY YM DATE 11/22/96

Lateral Soil Pressure Check

- Earth Force (E)



- $X_{cg} = \dfrac{\frac{1}{2}(2627)(1759)^2/3 - \frac{1}{2}(627)(1252)(1252/3+216) - (627)(216)^2/2}{\frac{1}{2}(2627)(1759) - \frac{1}{2}(627)(1252) - (627)(216)}$

$= 612$ $(612 + 383.8 = 995.8$ wrt wall front$)$

- $Y_{cg} = \dfrac{\frac{1}{2}(1759)(2627)^2(2/3) - \frac{1}{2}(1252)(627)(627\cdot 2/3 + 2000) - (216)(627)(627/2+2000)}{\frac{1}{2}(2627)(1759) - \frac{1}{2}(627)(1252) - (627)(216)}$

$= 1561$ from bot of wall

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-12 OF _____

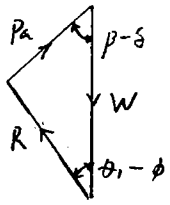
TITLE _____ BY YM DATE 11/22/96

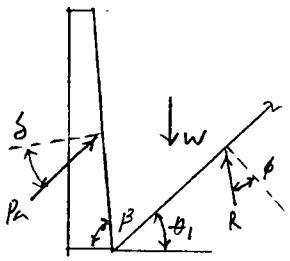
- Soil Wedge Weight $= \left[\frac{1}{2}(2627)(1759) - \frac{1}{2}(627)(1252) - (627)(216)\right](0.19\times10^{-4})$

$= 33.9\ N$

- Earth Force

Force Triangle





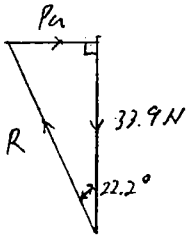
β = angle of inclination of face of wedge = 90°

θ_1 = angle of failure surface = 56.2°

δ = wall friction angle (derived from μ_{SS} in the program)

$= \tan^{-1} 0° = 0$

ϕ = Soil friction angle = 34°



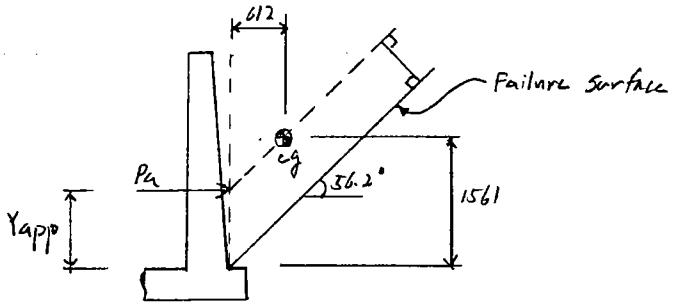
$P_a = 33.9 \tan 22.2 = 13.83\ N$ @ 0° from horizontal

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-13 OF _____

TITLE _____ BY YM DATE 11/22/96

- Earth Force Point of Application



$Y_{app} = 1561 - 612 \tan 56.2 = 646.8 < 0.333H = 666 \Rightarrow$ Use 666

$X_{app} = 383.8$ from front face of wall

- Equivalent earth pressure coefficient

$$P_a = \frac{1}{2} K_{a(equiv)} \gamma H^2$$

$$K_{a(equiv)} = 2P_a / \gamma H^2 = (2)(13.83) / (0.19 \times 10^{-4})(2000)^2$$

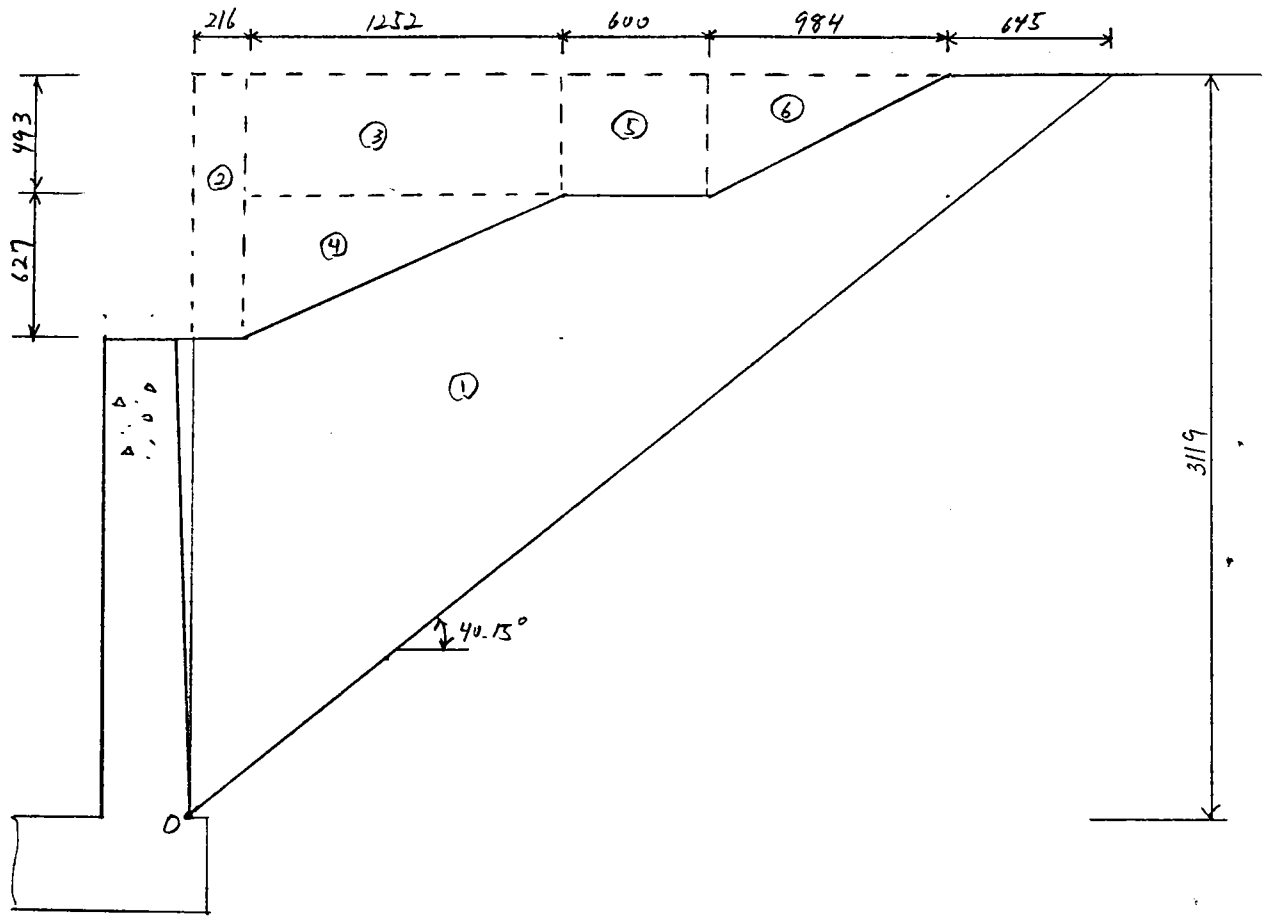
$$= 0.3639$$

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-14 OF _____

TITLE _____ BY YM DATE 11/22/96

o Seismic Force (EQE)



Section		Area	$\bar{x}$	$A\bar{x}$	$\bar{y}$	$A\bar{y}$
①	$\frac{1}{2}(3119)(3697)$ =	5765472	1232	7103068888	2079	$1.19864152 \times 10^{10}$
②	$(216)(1120)$ =	-241920	108	-26127360	2560	-619315200
③	$(1252)(493)$ =	-617236	842	-519712712	2874	-1773936264
④	$\frac{1}{2}(627)(1252)$ =	-392502	633	-248453766	2418	-949069836
⑤	$(493)(600)$ =	-295800	1768	-522974400	2874	-850129200
⑥	$\frac{1}{2}(493)(984)$ =	-242556	2396	-581164176	2956	-716995536
		3975458		5204628474		7076969214

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-15 OF _____

TITLE _____ BY YM DATE 11/22/96

- Soil Wedge Weight

$W = 3975458 \times 0.19 \times 10^{-4} = 75.53\ N$

- Center of Gravity of soil Wedge

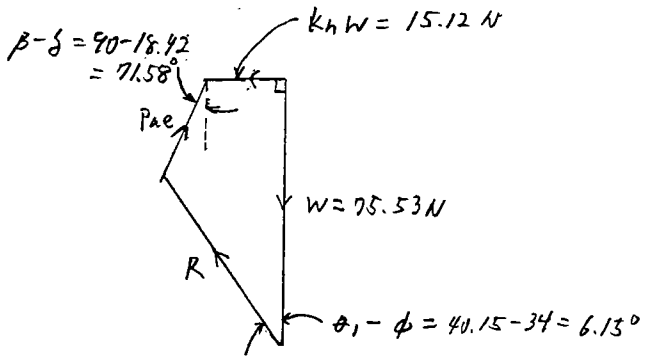
$X_{cg} = 5204628474 / 3975458 = 1309$ (1309 + 383.8 = 1692.8 wrt front of wall)

$Y_{cg} = 7076969214 / 3975458 = 1780$

- Seismic Force

$K_h = 0.2$, $k_v = 0$

Force polygon



$\delta = \tan^{-1} \mu_{ss}$

$= \tan^{-1}(0.333) = 18.42°$

Equilibrium

$\overset{\Sigma}{\rightarrow} F_x = P_{ae} \sin 71.58 - R \sin 6.15 - 15.12 = 0$

$+\uparrow \Sigma F_y = P_{ae} \cos 71.58 + R \cos 6.15 - 75.53 = 0$

$P_{ae} = 23.66\ N$ @ $\delta = 18.42°$ from horizontal

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-16 OF _____

TITLE _____ BY YM DATE 11/22/96

- Seismic Force - Point of Application

$Y_{app} = 1780 - 1309 \tan(90 - 40.15) = 228. < \frac{1}{2}H$

→ use $Y_{app} = \frac{1}{2}H = 1000$ from top of ftg

$X_{app} = 383.8$ from front of wall

- Equivalent earth pressure coefficient

$K_{aeq}(equiv) = 2P_{ae} / \gamma H^2 = (2)(23.66) / (0.19 \times 10^{-4})(2000)^2$

$= 0.6226$

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET C3-17 OF_____

TITLE_____ BY YM DATE 11/22/96

- Load Combination 1 (1.3D + 1.7E + 1.7SC)

  Shear = 13.83 × 1.7 = 23.51 N

  Moment = 23.51 × 666 = 0.1566 × 10^5 N·mm

- Load Combination 2 (1.3D + 1.3EQ)

  Shear = 23.66 cos 18.42° × 1.3 = 29.18 N

  Moment = 29.18 × 1000 = 0.2918 × 10^5 N·mm

- Maximum Loads

  Shear = 29.18 N

  Moment = 0.2918 × 10^5 N·mm

- Design Moment

  $M_{cr} = \frac{f_r I_g}{y_t}$ where: $f_r = 7.5\sqrt{f'_c}/12 = 7.5\sqrt{25}/12 = 3.125$

  $I_g = \frac{1}{12}(1)(383.8)^3 = 4711223.039$

  $y_t = \frac{1}{2}h = \frac{1}{2}(383.8) = 191.9$

  $M_{cr} = (3.125)(4711223.039)/191.9 = 76720$ N·mm > 0.2918 × 10^5 N·mm

  1.2 M_{cr} = 76720 × 1.2 = 92064 N·mm

  1.33 M_u = (1.33)(0.2918 × 10^5) = 0.3881 × 10^5 N·mm ← governs

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-18 OF_____

TITLE_____ BY YM DATE 11/22/96

- Required Steel Area

$$K_n = M/d^2 = 0.3881\times10^5 / (383.8 - 30 - 30/2)^2 = 0.3819$$

$$w = \frac{0.9f_c' - \sqrt{(0.9f_c')^2 - (4)(0.59)(0.9)f_c' K_n}}{(2)(0.59)(0.9f_c')}$$

$$= \frac{(0.9)(25) - \sqrt{(0.9\times25)^2 - (4)(0.59)(0.9)(25)(0.3819)}}{(2)(0.59)(0.9\times25)} = 0.01715$$

$$\rho = w\frac{f_c'}{f_s} = (0.01715)(25)/420 = 1.0206\times10^{-3}$$

$$A_s = \rho d = (1.0206\times10^{-3})(318.8) = 0.3254 \text{ mm}^2$$

- Max Steel Area

$\beta_1 = 0.85 \quad (f_c' < 30)$

$$\rho_{bal} = 0.85\beta_1 f_c'(600)/f_y(600+f_y)$$

$$= (0.85)(0.85)(25)(600)/(420)(600+420) = 0.02530$$

$$\rho_{max} = 0.5\rho_{bal} = 0.02530/2 = 0.01265$$

Max steel Area $= 0.01265bd = (0.01265)(1)(318.8) = 4.032 \text{ mm}^2$

- Shear Capacity

$$\phi V_c = (0.85)(2\sqrt{f_c'})(b)(d)/12 = (0.85)(2\sqrt{25})(1)(318.8)/12$$

$$= 225.8 \text{ N} > 29.18 \text{ N} \quad (\text{Ok})$$

CHECKED_____ DATE_____ JOB NO._____

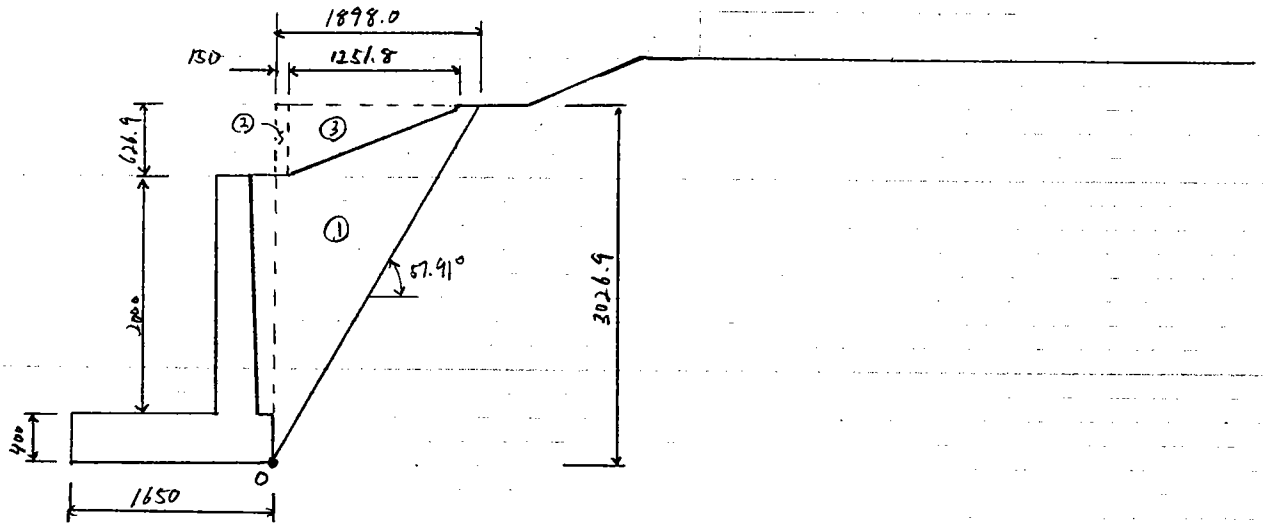
APPROVED_____ DATE_____ SHEET C3-19 OF_____

TITLE_____ BY YM DATE 11/22/96

External Stability

1. Trial Wedge Analysis

o Earth Force



Section	Area	$\bar{x}$	$A\bar{x}$	$\bar{y}$	$A\bar{y}$
①	2872328.1	632.7	1817448529	2017.9	5796474453
②	-94035.0	75.0	-7052625	2713.5	-255163972.5
③	-392376.7	567.3	-222582222.7	2817.9	-1105678303
	2386116.4		1587813681		4435632178

o Soil Wedge Weight

= 2386116.4 x (0.19×10^{-4}) = 45.33

o x_{cg}

= 1587813681 / 2386116.4 = 665.4 (+ 1650 = 2315.4 to ftg toe)

o y_{cg}

= 4435632178 / 2386116.4 = 1858.9

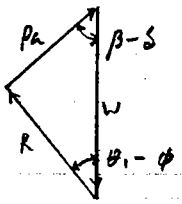
CHECKED_____ DATE _____ JOB NO._____

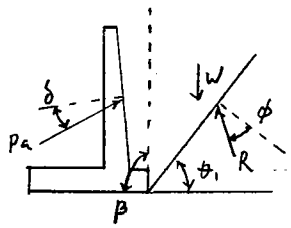
APPROVED_____ DATE _____ SHEET C3-20 OF_____

TITLE_____ BY YM DATE 11/22/96

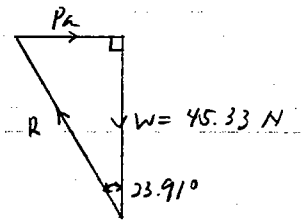
• Earth Force

- Force Triangle





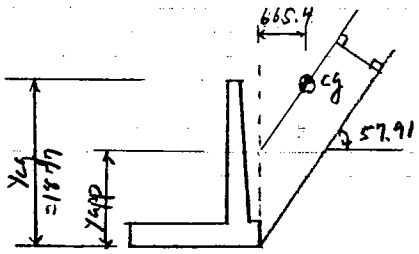
$\beta = 90°$, $\theta_1 = 57.91°$, $\delta = \tan^{-1} 0° = 0$, $\phi = 34°$



$Pa = 45.33 \tan 23.91 = 20.10$ N

@ 0° from horizontal

• Earth Force Point of Application



$Y_{app} = 1859 - 665.4 \tan 57.91 = 797.9$

$0.333H = (0.333)(2400) = 799.2 > 797.9$

⇒ use $Y_{app} = 799.2$

$X_{app} = 1650$ from ftg toe

• Equivalent Earth Pressure Coefficient

$P_a = \frac{1}{2} K_{a(equiv)} \gamma H^2$

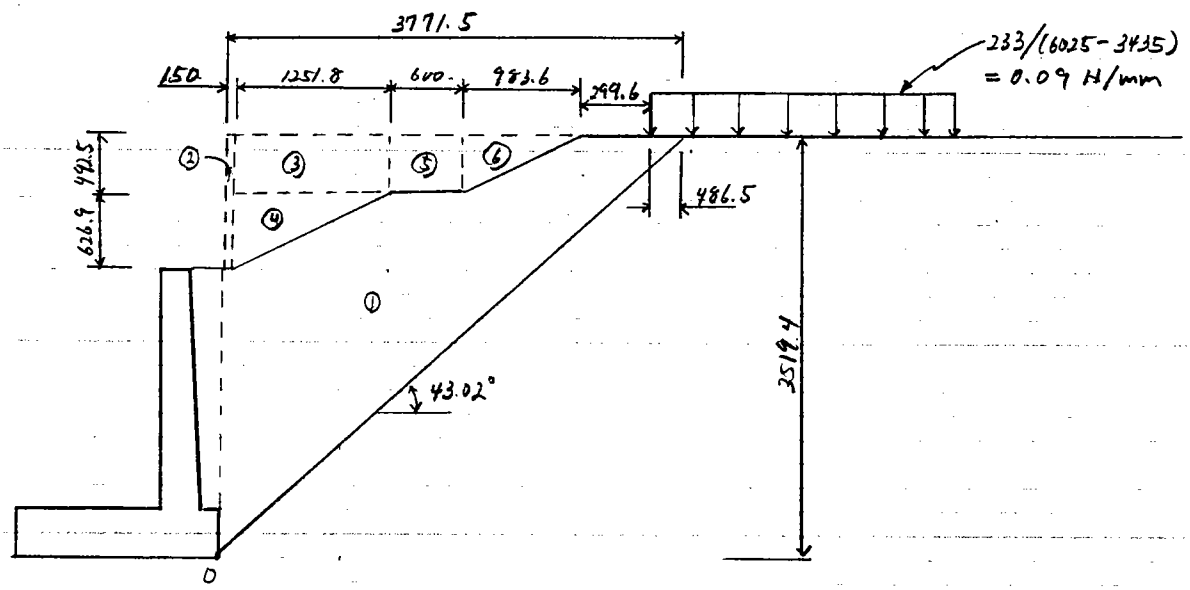
$K_{a(equiv)} = 2P_a / \gamma H^2 = (2)(20.10) / (0.19 \times 10^{-4})(2400)^2 = 0.3673$

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-21 OF_____

TITLE_____ BY YM DATE 11/22/96

• E + SUR Force



Note: See spreadsheet on next page for calculations

• Soil wedge weight

= 7226672.52 x (0.19 x10⁻⁴) = 137.3 N

• Xcg

= 14693547324.93 / 7226672.52 = 2033.24 (+1650 = 3683.2 from ftg toe)

• Ycg

= 18281395777.22 / 7226672.52 = 2529.7

SECTION	AREA	x	Ax	y	Ay
1	6636708.55	1257.17	8343470887.80	2346.27	15571510169.61
2 (-)	167910.00	75.00	12593250.00	2959.70	496963227.00
3 (-)	616511.50	775.90	478351272.85	3273.15	2017934616.23
4 (-)	392376.71	567.27	222583536.28	2817.93	1105690102.41
5 (-)	295500.00	1701.80	502881900.00	3273.15	967215825.00
6 (-)	242211.50	2329.67	564272865.21	3355.23	812675291.15
SUR	2304473.68	3528.25	8130759261.46	3519.40	8110364669.39
Σ	7226672.52		14693547324.93		18281395777.22

W(wedge)	137.31
Xcg	2033.24
Ycg	2529.71

"Area" for SUR has been expressed in terms of geometric area to be consistant with other sections

Area = $0.09\ N/mm \times 486.5\ mm \div 0.19 \times 10^{-4}\ N/mm^3 = 2304473.68\ mm^2$

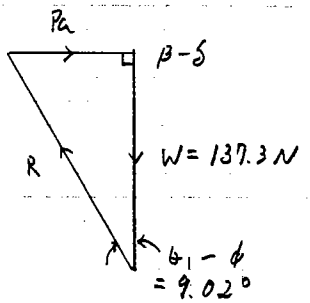
CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-23 OF_____

TITLE_____ BY YM DATE 11/22/96

° E+ SUR Force

- Force Triangle



$\beta = 90°$

$\theta_1 = 43.02°$

$\delta = 0$

$\phi = 34°$

$Pa = 137.3 \tan 9.02° = 21.80\ N$ @ 0° from horizontal

° E+ SUR Force Point of Application

$y_{app} = 2530 - 2019.9 \tan 43.02 = 645.1 < 0.333H = 799.2$

⇒ use $y_{app} = 799.2$

$x_{app} = 1650$ from ftg toe

° Equivalent Earth Pressure Coefficient

$K_a(equiv) = 2Pa / \gamma H^2 = (2)(21.80) / (0.14 \times 10^{-4})(2400)^2$

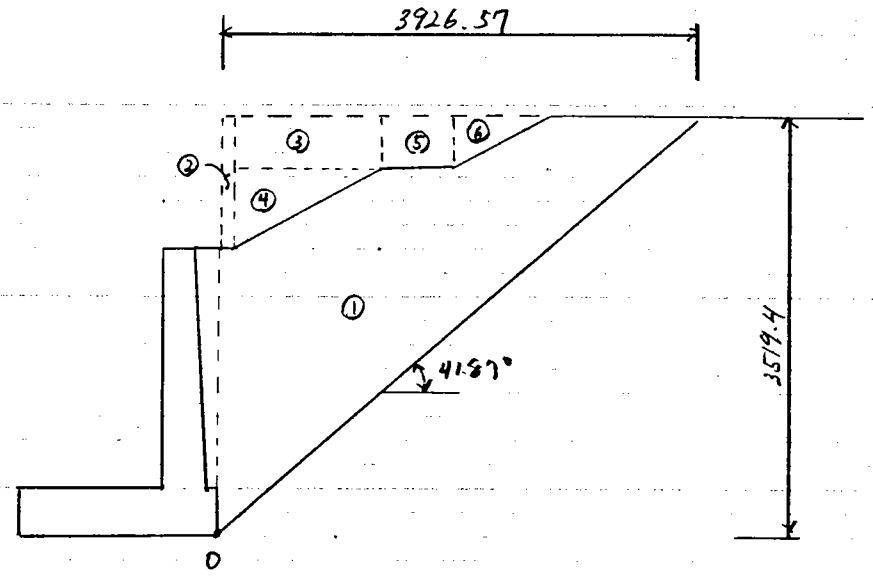
$= 0.3984$

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-24 OF_____

TITLE_____ BY YM DATE 11/22/96

o Seismic force



Refer to "E+SUR" section

Σ Area = 7226672.52 − 6636708.55 − 2304473.68 + $\frac{1}{2}$(3926.57)(3519.4)

= 5195075.52

$\Sigma A\bar{x}$ = 145969899877.73 − 83434708887.80 − 80342018142.27

+ $\frac{1}{2}$(3519.4)(3926.57)^2/3 = 72629738 60

$\Sigma A\bar{y}$ = 182813957777.22 − 155715101 69.61 − 81103646 69.39

+ $\frac{1}{2}$(3926.57)(3519.4)^2(2/3) = 108112504 40

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-25 OF_____

TITLE_____ BY YM DATE 11/22/96

- Soil Wedge Weight

  $= 5195075.52 \times (0.19 \times 10^{-4}) = 98.71\ N$

- Xcg

  $= 7262973860 / 5195075.52 = 1398.0$ (+1650 = 3048.0 from fig toe)

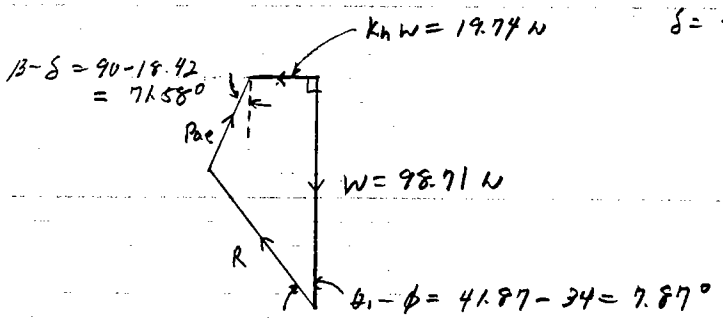
- Ycg

  $= 10811250440 / 5195075.52 = 2081.1$

- Seismic Force

  $k_h = 0.2, \quad k_v = 0$

- Force Polygon



$\delta = \tan^{-1}(0.333) = 18.42°$

$\overset{+}{\Sigma} F_x = P_{ae} \sin 71.58 - R \sin 7.87 - 19.74 = 0$

$+\uparrow \Sigma F_y = P_{ae} \cos 71.58 + R \cos 7.87 - 98.71 = 0$

$P_{ae} = 33.64\ N$ @ $\delta = 18.42°$ from horizontal

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-26 OF_____

TITLE_____ BY YM DATE 11/22/96

o Seismic Force Point of Application

$Y_{app} = 2081 - 1398 \tan 41.87° = 827.0 \Rightarrow$ use $\frac{1}{2}H = 1200$

$X_{app} = 1650$

o Equivalent Earth Pressure Coefficient

$K_{a\,eq\,(equiv)} = 2P_{ae} / \gamma H^2 = (2)(33.64) / (0.19 \times 10^{-4})(2400)^2$

$= 0.6148$

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET C3-27 OF_____

TITLE_____ BY YM DATE 11/22/96

o Load Combination 2 (D + EQ)

Lateral Force = $33.64 \cos 18.42° = 31.92$ N

Overturning Moment = $31.92 \times 1200 = 0.3830 \times 10^5$ N·mm

Total Weight = $42.67 + 31.92 \times 0.333 = 53.30$ N

Righting Moment = $0.4565 \times 10^5 + 31.92 \times 0.333 \times 1650 = 0.6319 \times 10^5$ N·mm

Sliding Weight = 42.67 N

Sliding Resistance = $(42.67)(0.4) + \frac{1}{2}(3.333)(0.19 \times 10^{-4})(300 + 400 + 300)^2$

$= 48.73$ N

Sliding SF = $48.73 / 31.92 = 1.53 > 1.20$ (ok)

Overturning SF = $0.6319 \times 10^5 / 0.3830 \times 10^5 = 1.65 > 1.50$ (ok)

Soil Pressure

$M_{Tot} = 0.6319 \times 10^5 - 0.3830 \times 10^5 = 0.2489 \times 10^5$

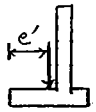
$\text{eccentricity} = \frac{1650}{2} - \frac{0.2489 \times 10^5}{53.30} = 358.0$

$I = \frac{1}{12}(1650)^3 = 374343750$ mm^4

$q = \frac{53.30}{1650} \pm \frac{(53.30)(358.0)(1650/2)}{374343750}$

* final ⇒ negative value

$e' = 0.2489 \times 10^5 / 53.30 = 466.98$



$\frac{1}{2} q_{max}(3e') = \text{Tot. weight}$

$q_{max} = (2)(\text{Tot weight})/3e' = (2)(53.30)/(3)(466.98) = 0.7610 \times 10^{-1}$

< 0.2550

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-28 OF _____

TITLE _____ BY YM DATE 11/22/96

- Load Combination 1 (D + E + SC)

Lateral force = 21.80 N (from previous calc)

Overturning Moment = 21.80 N × 800 mm = 17440 N·mm

Total Weight = 42.67 N (see "wall configuration)

Righting Moment = 0.4585×10^5 (see "Wall Configuration")

Sliding Resistance = (Weight) $\mu_{sc} + \frac{1}{3} K_p \gamma H_p^2$

$= (42.67)(0.4) + \frac{1}{3}(1.667)(0.19 \times 10^{-4})(300+400+300)^2$

$= 32.90$

Sliding SF = 32.90 / 21.80 = 1.51 > 1.50 (Ok)

Overturning SF = $0.4585 \times 10^5 / 17440 = 2.62 > 2.00$ (Ok)

Surl Pressure

$M_{TOT} = 0.4585 \times 10^5 - 17440 = 28210$

eccentricity = $\frac{1650}{2} - 28210 / 42.67 = 163.9$

$I = \frac{1}{12}(1650)^3 = 374343750$

$q = \frac{42.67}{1650} \pm \frac{(42.67)(163.9)(1650/2)}{374343750}$

$q_{toe} = 0.4127 \times 10^{-1} < 0.1920$ (Ok)

$q_{heel} = 0.1045 \times 10^{-1}$

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-29 OF _____

TITLE _____ BY YM DATE 11/22/96

Footing Design

- Load Combination 1 (1.3D + 1.7E + 1.75C)

Lateral Force = 21.80 × 1.7 = 37.06

Overturning = $0.1744 \times 10^5 \times 1.7 = 0.2965 \times 10^5$

Weight = 42.67 × 1.3 = 55.47

Righting Moment = $0.4565 \times 10^5 \times 1.3 = 0.5935 \times 10^5$

Soil Pressure

$M_{TOT} = 0.5935 \times 10^5 - 0.2965 \times 10^5 = 0.2970 \times 10^5$

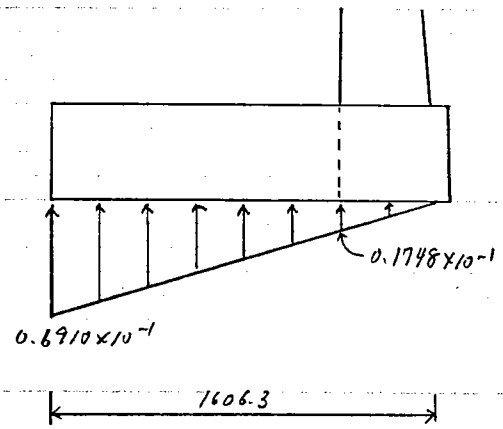
$\text{Eccentricity} = \frac{1650}{2} - \frac{0.2970 \times 10^5}{55.47} = 289.6$

$e' = 0.2970 \times 10^5 / 55.47 = 535.4$

$3e' = 535.4 \times 3 = 1606.3 < 1650 \Rightarrow$ Ftg in partial compression

$q_{max} = (2)(55.47) / 1606.3 = 0.6910 \times 10^{-1}$

Note: For LC 1, Steel Area will change after corrected the bug!!

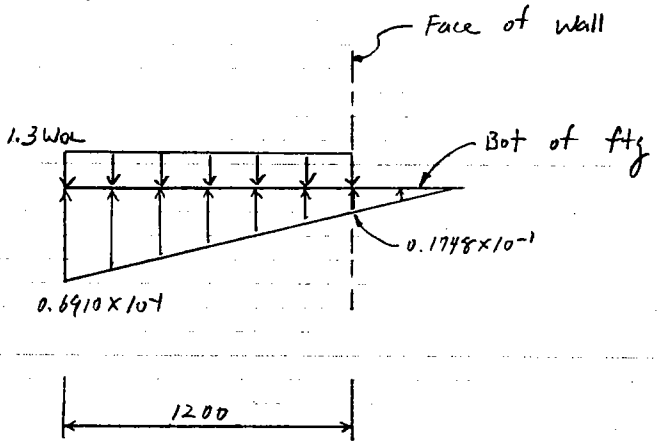


CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-30 OF_____

TITLE_____ BY YM DATE 11/22/96

Footing Toe



$1.3\,W_{DL} = [(0.19\times10^{-4})\times 300 + (0.2310\times10^{-4})\times 400](1.3) = 0.1968\times10^{-1}$

$Shear = (0.1748\times10^{-1})(1200.) + \frac{1}{2}(0.6910\times10^{-1} - 0.1748\times10^{-1})(1200) - (0.1968\times10^{-1})(1200)$

$= 20.976 + 30.972 - 23.616 = 28.33\ N$

$Moment = 20.976\times600 + 30.972\times800 - 23.616\times600 = 0.2319\times10^{5}\ N\cdot mm$

* Compute Mcr in English units and convert back to metric

$M_{cr} = \frac{f_r I_g}{y_t}$ where: $f_r = 7.5\sqrt{f_c'} = 7.5\sqrt{3625.974\ psi}$

$= 451.62\ psi$

$I_g = \frac{1}{12}(\frac{1}{25.4}\ in)(15.748\ in)^3$

$= 12.81\ in^4$

$y_t = \frac{1}{2}h = 15.748/2 = 7.874\ in$

$M_{cr} = (451.62)(12.81)/7.874 = 734.73\ lb\cdot in$

$= 83013\ N\cdot mm$

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C3-31 OF_____

TITLE_____ BY YM DATE 11/22/96

$1.2 M_{cr} = (1.2)(83013) = 99616 \quad N \cdot mm$

$1.33 M_u = (1.33)(0.2319 \times 10^5) = 0.3084 \times 10^5 \quad N \cdot mm \leftarrow$ governs

- Shear Capacity

$\phi V_c = (0.85)(2\sqrt{f_c'})(b)(d)/12$

$= (0.85)(2\sqrt{25})(1)(400 - 75 - 30/2)/12$

$= 219.6 \ N > 28.33 \ N$ (OK)

- Moment Capacity

$\rho = \frac{A_s}{bd} = \frac{0.3951}{(1)(400-75-30/2)} = 1.2745 \times 10^{-3}$

$\phi M_n = 0.9\left[A_s f_y d\left(1 - 0.6\frac{\rho f_y}{f_c'}\right)\right]$

$= 0.9\left[(0.3951)(420)(310)\left(1 - (0.6)\frac{(1.2745\times10^{-3})(420)}{25}\right)\right]$

$= 0.4570 \times 10^5 \ N \cdot mm > 0.3084 \times 10^5 \ N \cdot mm$ (OK)

- Max Steel Area

$\beta_1 = 0.85 \quad (f_c' < 30)$

$\rho_{bal} = 0.85\beta_1 f_c'(600)/[f_y(600+f_y)]$

$= (0.85)(0.85)(25)(600)/[(420)(600+420)] = 0.02530$

$\rho_{max} = 0.5\rho_{bal} = 0.02530/2 = 0.01265$

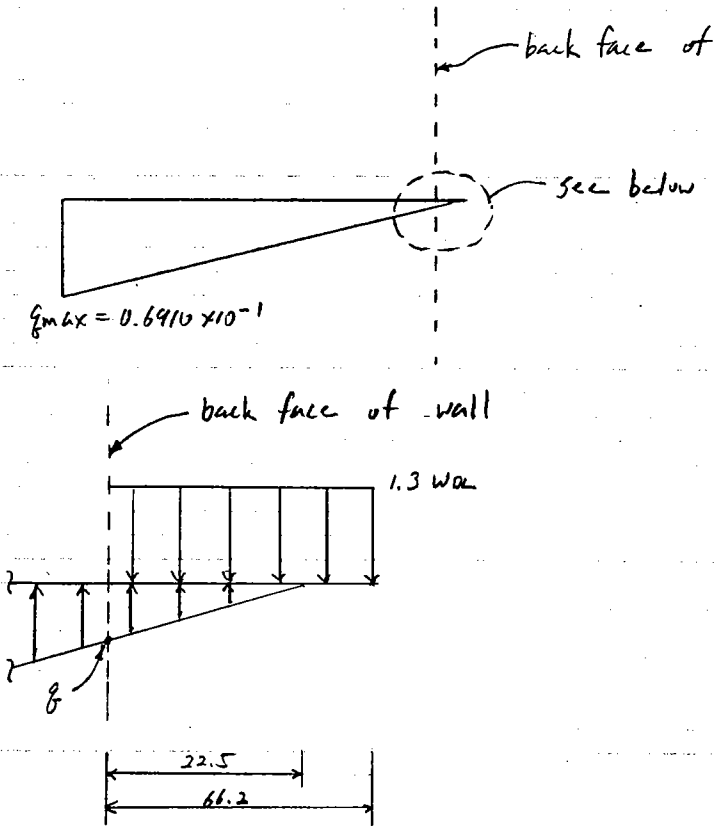
Max steel area $= 0.01265\,bd = (0.01324)(1)(310) = 3.921 \ mm^2$

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET C3-32 OF _____

TITLE _____ BY YM DATE 11/22/96

Footing Heel



$1.3 W_{DL} = (1.3)[(2000)(0.19 \times 10^{-4}) + (400)(0.2360 \times 10^{-4})] = 0.061672$

$q = \frac{0.6910 \times 10^{-1}}{1606.3} \times 22.5 = 9.679 \times 10^{-4}$

$Shear = (0.061672)(66.2) - \frac{1}{2}(9.679 \times 10^{-4})(22.5) =$

$= 4.082 - 0.01089 = 4.071\ N$

$Moment = (4.082)(66.2/2) - (0.01089)(22.5/3) = 135.0\ N \cdot mm$

$1.2 M_{cr} = 99616\ N \cdot mm$

$1.33 M_n = (1.33)(135.0) = 179.6\ N \cdot mm$ ← governs

CHECKED_____ DATE_____ JOB NO._____

APPROVED_____ DATE_____ SHEET C3-33 OF_____

TITLE_____ BY YM DATE 11/22/96

- Shear Capacity

$\phi V_c = (0.85)(2\sqrt{f_c'})(b)(d)/12$

$= (0.85)(2\sqrt{25})(1)(400-50-30/2)/12 = 237.3\ N > 4.071\ N$ (Ok)

- Moment Capacity

$\rho = \frac{A_s}{bd} = \frac{0.01380}{(1)(335)} = 4.119 \times 10^{-5}$

$\phi M_n = 0.9\left[A_s f_y d\left(1 - 0.6\frac{\rho f_y}{f_c'}\right)\right]$

$= 0.9\left[(0.0138)(420)(335)\left(1 - 0.6\frac{(4.119\times10^{-5})(420)}{25}\right)\right]$

$= 1747\ N\cdot mm > 179.6\ N\cdot mm$ (OK)

- Max Steel Area

$\rho_{max} = 0.01265$

Max Steel Area $= 0.01265\,bd = (0.01265)(1)(335) = 4.238\ mm^2$

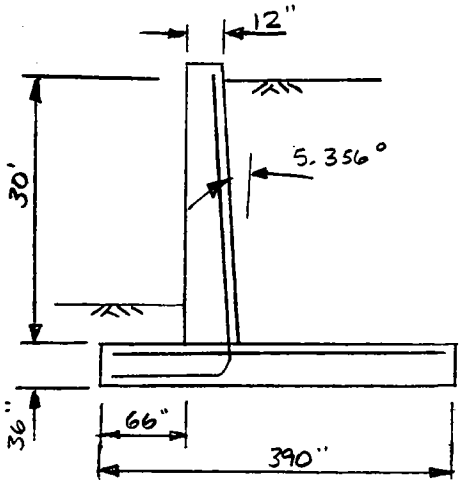
CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET CA-1 OF_____

TITLE Caltran LARTMC BY Rm DATE 9/9/99

RETAINING WALL VERIFICATION PROBLEM

Design height = 30'



Soil unit weight = .0694 lbs/in^3

Concrete unit weight = .0868 lbs/in^3

Loads: $K_a = 0.3$

$K_{aeq} = 0.73$ at 0.6H (increment)

Surcharge = 1.67 psi

- Wall design

Combo 1: $V_u = (0.3 \times .0694 \times (360)^2/2 + 0.3 \times 1.67 \times 360)(1.7)$

$V_u = 2600$ lbs

$M_u = (.02082(360)^3/6 + .501(360)^2/2)(1.7)$

$M_u = 330400$ in-lbs

Combo 2: $V_u = .02082(360)^2/2 + .73 \times .0694(360)^2/2 = 4632$ lbs

$M_u = .02082(360)^3/6 + 3283(0.6)(360) = 871000$ in-lbs

Shear: $T = 12 + 372 \tan 5.356 = 46.88$ in

$d = 46.88 - 2 - 1.625/2 = 44.06$ in

$\phi V_c = 0.85 \times 2\sqrt{4000} \times 1 \times 44.06 = 4738$ lbs > 4632 OK

Moment: $A_s = 0.508$ in^2/ft

$\phi M_n = 1085600$ in-lbs > 871000 OK

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C4-2 OF_____

TITLE Caltrans LARTMC BY RM DATE 9/9/99

- Weight and Righting Moment

Wall	$12 \times 372 \times .0868 = 387.5$	$\bar{X} = 72$
	$34.9 \times 372 \times .0868/2 = 563.5$	$\bar{X} = 89.6$
Ftg	$36 \times 390 \times .0868 = 1218.7$	$\bar{X} = 195$
Soil	$12 \times 66 \times .0694 = 55.0$	$\bar{X} = 33$
	$277.1 \times 360 \times .0694 = 6923.1$	$\bar{X} = 251.5$
	$34.9 \times 372 \times .0694/2 = 450.5$	$\bar{X} = 101.3$

Dead load = 9598 lbs

M_r = 2104600 m-lbs

Surcharge load = $1.67 \times 312 = 521$ lbs

M_r = 121900 m-lbs

- External Stability Analysis

Combo 1: Lateral force = $.02082(396)^2/2 + .501(396) = 1831$ lbs

$M_{ot} = .02082(396)^3/6 + .501(396)^2/2 = 254800$ m-lbs

Weight = 9598 + 521 = 10119 lbs

M_R = 2104600 + 121900 = 2226500 m-lbs

Sliding resistance = $10119 \times 0.75 = 7589$ lbs

Sliding SF = $\frac{7589}{1831} = 4.14 > 1.5$ (OK)

Overturning SF = $\frac{2226500}{254800} = 8.74 > 2.0$ (OK)

Soil pressure:

eccentricity = $\frac{390}{2} - \frac{(2226500 - 254800)}{10119} = 0.15$ m

$Q_{toe} = \frac{10119}{390} + \frac{10119(.15)(6)}{(390)^2} = 26.0$ psi

$Q_{heel} = \frac{10119}{390} - \frac{10119(.15)(6)}{(390)^2} = 25.9$ psi

$Q_{allow} = 27.78 > 26$ (OK)

CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET CA-3 OF_____

TITLE Caltrans LARTMC BY RM DATE 9/9/99

Combo 2: Lateral force = $.02082(396)^2/2 + .05066(396)^2/2 = 5605$ lbs

Mot = $.02082(396)^3/6 + 3972(.6)(396) = 1159200$ m-lbs

Vertical component at heel = $0.33 \times 5605 = 1850$ lbs

Total weight = $1850 + 9598 = 11448$ lbs

$M_R = 2104600 + 1850 \times 390 = 2826100$ in-lbs

Sliding resistance = $11448 \times 0.75 + 1.88 \times .0694(48)^2/2$

$= 8736$ lbs

Sliding SF = $\frac{8736}{5605} = 1.56 > 1.2$ OK

Overturning SF = $\frac{2826100}{1159200} = 2.44 > 1.5$ OK

Soil pressure:

eccentricity = $\frac{390}{2} - \frac{(2826100 - 1159200)}{11448} = 49.4"$

$Q_{toe} = \frac{11448}{390} + \frac{11448(49.4)(6)}{(390)^2} = 51.66$ psi

$Q_{heel} = 7.04$ psi

$Q_{allow} = 55.55 > 51.66$ OK

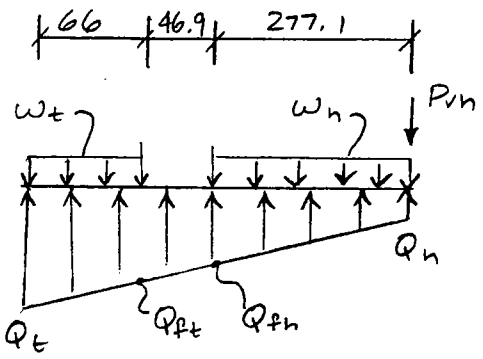
CHECKED_____ DATE _____ JOB NO._____

APPROVED_____ DATE _____ SHEET C4-4 OF_____

TITLE Caltrans LARTMC BY Rm DATE 9/9/99

- Footing Design

Combo 2 Critical by inspection



w_t = .0868 x 36 + 12 x .0694 = 3.96 psi

w_h = .0868 x 36 + 360 x .0694 = 28.11 psi

P_{vh} = 1850 lbs

Q_t = 51.66 psi

Q_h = 7.04 psi

> TOE Q_{ft} = 51.66 - .1144 x 66 = 44.11 psi

$V_u = (44.11 - 3.96)(66) + .1144(66)^2/2 = 2899$ lbs

$M_u = 40.15(66)^2/2 + .1144(66)^3/3 = 98410$ in-lbs

$d = 36 - 3 - 1.625/2 = 32.19$ in

$\phi V_c = 0.85 \times 2\sqrt{4000} \times 32.19 = 3461$ lbs > 2899 (OK)

$A_s = 0.254$ in^2/ft

$\phi M_n = 410800$ in-lbs > $1.2 M_{cr} = 122950$ in-lbs (OK)

CHECKED _____ DATE _____ JOB NO. _____

APPROVED _____ DATE _____ SHEET CA-5 OF _____

TITLE Caltrans LARTMC BY RM DATE 9/9/99

> HEEL $\varphi_{fh} = 51.66 - .1144 \times 112.9 = 38.74$ psi

$V_u = (28.11 - 7.04)(277.1) - .1144(277.1)^2/2 + 1850 = 3296$ lbs

$M_u = 21.07(277.1)^2/2 + 1850(277.1) - .1144(277.1)^3/6 = 915900$ in-lbs

$d = 33.19$ in

$\phi V_c = 0.85 \times 2\sqrt{4000} \times 33.19 = 3569$ lbs $>$ 3296 (OK)

$A_s = 0.629$ in^2/ft

$\phi M_n = 932900$ in-lbs $>$ 915900 (OK)

RETAIN PROGRAM OUTPUT

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   R E T A I N                   *
*                                                         *
*                 INPUT DATA ECHO                         *
*                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
(Version  1.42)                5/02/2007,  5:08:40

Input file  = ver4.IN
Output file = ver4_1.42.out

P R O G R A M   O P T I O N S
=====================================================

PROGRAM UNITS      =  1 (English: inches/pounds/degrees)
ANALYSIS MODE      =  2 (Review)
CONCRETE DESIGN    =  1 (Ultimate strength)
SOIL CONFIGURATION =  1 (Constant slope)
FOUNDATION TYPE    =  1 (Spread footing)

M A T E R I A L   P R O P E R T I E S
=====================================================

CONCRETE PROPERTIES:

     Concrete unit weight          = 0.8680E-01
     Concrete compressive strength =  4000.
     Reinforcing steel strength    = 0.6000E+05

SOIL PROPERTIES:

     Soil unit weight              = 0.6940E-01
     Soil friction angle           =  0.000
     Soil base cohesion            =  0.000

S O I L   P A R A M E T E R S
=====================================================

LATERAL PRESSURE COEFFICIENT:

     Regular loads =  0.300  @ Y =  0.333H
     Seismic loads =  0.730  @ Y =  0.600H

PASSIVE PRESSURE COEFFICIENT:

     Regular loads =  0.000
     Seismic loads =  1.880
```

```
SOIL/SOIL FRICTION COEFFICIENT:

     Regular loads =  0.000
     Wind loads    =  0.000
     Seismic loads =  0.330

SOIL/SOIL FRICTION OPTION:

     Option        =  1 (Use Pa vert component)

L O A D S
=====================================================

LOADS AT TOP OF WALL:

     Dead load      =  0.000      @ X =  0.000
     Live load      =  0.000      @ X =  0.000
     Wind shear     =  0.000
     Wind moment    =  0.000
     Seismic shear  =  0.000
     Seismic moment =  0.000

LOAD COMBINATIONS:

      1.400D + 0.000L + 1.700E + 1.700SC + 0.000W + 0.000EQ
      1.000D + 0.000L + 1.000E + 0.000SC + 0.000W + 1.000EQ

S O I L   C O N F I G U R A T I O N
=====================================================

Design height           =  360.0
Height of soil over toe =  12.00
Backfill slope angle    =  0.000

Uniform surcharge       =  1.670

W A L L   C O N F I G U R A T I O N
=====================================================

Minimum wall thickness    =  13.10
Wall batter               =  5.356
Footing thickness         =  36.00
Key depth                 =  0.000
Toe width                 =  66.00
Footing width             =  390.0

R E B A R   C O N F I G U R A T I O N
=====================================================

REINFORCING STEEL INFORMATION:

     Bar diameter            =  1.625
     Ratio of balanced reinf = 0.7500
```

```
CONCRETE COVER:

     At wall backface        =  2.000
     At footing top          =  2.000
     At footing bottom       =  3.000

REINFORCING STEEL AREA:

     At wall backface        = 0.5080
     At footing top          = 0.6240
     At footing bottom       = 0.2540

S P R E A D   F O O T I N G
=====================================================

ALLOWABLE SOIL BEARING PRESSURE:

     Regular loads =  27.78
     Wind loads    =  37.03
     Seismic loads =  55.55

CONCRETE/SOIL FRICTION COEFFICIENT:

     Regular loads =  0.750
     Wind loads    =  0.750
     Seismic loads =  0.750

OVERTURNING SAFETY FACTORS:

     Regular loads =  2.000
     Wind loads    =  1.500
     Seismic loads =  1.500

SLIDING SAFETY FACTORS:

     Regular loads =  1.500
     Wind loads    =  1.200
     Seismic loads =  1.200
```

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                           *
*           P R O G R A M   R E T A I N                     *
*                                                           *
*                     OUTPUT DATA                           *
*                                                           *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

W A L L   D E S I G N
=====================================================

LOAD COMBINATION   1:

  Shear  =  2600.
  Moment = 0.3301E+06

LOAD COMBINATION   2:

  Shear  =  4632.
  Moment = 0.8708E+06

MAXIMUM LOADS:

  Shear  =  4632.
  Moment = 0.8708E+06

    Shear capacity  =  4735.     > Design shear  =  4632.     OKAY
    Moment capacity = 0.1085E+07 > Design moment = 0.8708E+06 OKAY
    Steel area      = 0.5080     < Max stl area  = 0.9416     OKAY

W A L L   L O A D   D I S T R I B U T I O N
=====================================================

     DEPTH     SHEAR    MOMENT     THICK   AS REQD

       24.      347.     5573.    15.344     0.008
       48.      689.    22176.    17.587     0.028
       72.     1026.    37307.    19.831     0.041
       96.     1357.    65822.    22.074     0.065
      120.     1682.   102294.    24.318     0.092
      144.     2002.   146510.    26.561     0.120
      168.     2316.   198335.    28.805     0.149
      192.     2625.   257637.    31.048     0.179
      216.     2928.   324285.    33.292     0.210
      240.     3226.   398145.    35.535     0.241
      264.     3518.   479086.    37.779     0.273
      288.     3805.   566974.    40.022     0.304
      312.     4086.   661678.    42.266     0.336
      336.     4362.   763065.    44.509     0.368
      360.     4632.   871002.    46.753     0.399
```

```
W E I G H T   A N D   R I G H T I N G   M O M E N T
=====================================================

DEAD LOAD       =  9556.
RIGHTING MOMENT = 0.2101E+07

LIVE LOAD       =  0.000
RIGHTING MOMENT =  0.000

SURCHARGE LOAD  =  519.2
RIGHTING MOMENT = 0.1218E+06

E X T E R N A L   S T A B I L I T Y   A N A L Y S I S
=====================================================

LOAD COMBINATION   1:

  Lateral force      =  1831.
  Overturning moment = 0.2546E+06
  Total weight       = 0.1008E+05
  Righting moment    = 0.2222E+07
  Sliding resistance =  7557.

  Sliding SF         =   4.13     >   1.50     OKAY
  Overturning SF     =   8.73     >   2.00     OKAY

  SOIL PRESSURE:

    Eccentricity  = -.3074
    Toe pressure  =  25.71
    Heel pressure =  25.96

    Max pressure  =  25.96     <  27.78     OKAY

LOAD COMBINATION   2:

  Lateral force      =  5605.
  Overturning moment = 0.1159E+07
  Total weight       = 0.1141E+05
  Righting moment    = 0.2822E+07
  Sliding resistance =  8705.

  Sliding SF         =   1.55     >   1.20     OKAY
  Overturning SF     =   2.43     >   1.50     OKAY

  SOIL PRESSURE:

    Eccentricity  =  49.21
    Toe pressure  =  51.39
    Heel pressure =  7.103

    Max pressure  =  51.39     <  55.55     OKAY
```

```
F O O T I N G   D E S I G N
=====================================================

LOAD COMBINATION   1:

  Lateral force      =  3112.
  Overturning moment = 0.4327E+06
  Weight             = 0.1426E+05
  Righting moment    = 0.3148E+07

  SOIL PRESSURE:

    Eccentricity  =  4.619
    Toe pressure  =  39.17
    Heel pressure =  33.97

  FOOTING TOE:

    Shear  =  2190.
    Moment = 0.7260E+05

    Shear capacity  =  3461.     > Design shear  =  2190.     OKAY
    Moment capacity = 0.4107E+06 > Design moment = 0.9680E+05 OKAY
    Steel area      = 0.2540     < Max stl area  = 0.6882     OKAY

  FOOTING HEEL:

    Shear  =  1767.
    Moment = 0.2685E+06

    Shear capacity  =  3568.     > Design shear  =  1767.     OKAY
    Moment capacity = 0.9322E+06 > Design moment = 0.2685E+06 OKAY
    Steel area      = 0.6240     < Max stl area  = 0.7096     OKAY

LOAD COMBINATION   2:

  Lateral force      =  5605.
  Overturning moment = 0.1159E+07
  Weight             = 0.1141E+05
  Righting moment    = 0.2822E+07

  SOIL PRESSURE:

    Eccentricity  =  49.21
    Toe pressure  =  51.39
    Heel pressure =  7.103
```

```
FOOTING TOE:

  Shear  =  2883.
  Moment = 0.9786E+05

  Shear capacity  =  3461.     > Design shear  =  2883.     OKAY
  Moment capacity = 0.4107E+06 > Design moment = 0.1229E+06 OKAY
  Steel area      = 0.2540     < Max stl area  = 0.6882     OKAY

FOOTING HEEL:

  Shear  =  3310.
  Moment = 0.9165E+06

  Shear capacity  =  3568.     > Design shear  =  3310.     OKAY
  Moment capacity = 0.9322E+06 > Design moment = 0.9165E+06 OKAY
  Steel area      = 0.6240     < Max stl area  = 0.7096     OKAY
```