

Structural Engineering Library

Version 5.8

by Michael D. Brooks, S.E., P.E.

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Vesion 5.8 User's Reference

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Foreword

This software system was designed and developed to give the practicing Structural Engineer a tool to rapidly perform structural analysis and design of building components.

The design philosophy has remained the same for the last 20 years.....provide software that is a "fill-in'the-blanks" tool with instant recalculation and review of the results.

We thank the thousands of engineers who have purchased ENERCALC software over the last two decades helping this software develop to where it is today.

Part



1 Welcome

Welcome To The Structural Engineering Library

You've chosen one of the most respected Structural Engineering software packages available today. In continuous development since 1983 , Version 5.8 is the culmination of years of development and refinement from suggestions of engineers worldwide.

This document provides detailed documentation for all the modules contained in Vesion 5.8 of the Structural Engineering Library.

Please refer to Volume I for general information including licensing, installation, usage instructions, and a sample session.

Part



2 Concrete Design Modules

The programs in this section provide analysis and design for structural elements made of concrete.

Code References

Program modules for CONCRETE design are designed to be in conformance with the ACI 318-02 Edition. Concrete design is performed using "Ultimate Strength" analysis & design procedures using factored loads and reduced allowable capacities.

- Design procedures for concrete design follow ACI 318-02.
- **IBC 2003** Section 1901.2 references ACI 318 for the design of concrete.
- **1997 UBC** Chapter 19 Division II references ACI-318 for the design of concrete.
- **2003 NFPA 5000** Section 35.2.7.2 references ACI-318 for the design of concrete.
- Load combinations are according to ACI 318-02 Section C.2

Multi Span Concrete Beam

Multi Span Concrete Beam allows design of up to eight spans on one calculation sheet. Two modes are available; all spans can be simply supported with optional cantilevers or all are continuous with optional cantilevers and end fixities (pin,fix,free). Dead, live, and short term point, moment, and uniform/trapezoidal loads in any combination may be applied. Alternate span live loading is easily defined, and you can specify top & bottom reinforcing at left, center, and right positions for each span. Actual and allowable moments and shears, reactions, deflections, and shear stirrup spacings at sixth points along each span are given.

Rectangular Concrete Beam Design

Rectangular Concrete Beam Design provides more detailed and flexible design options for both rectangular and tee shaped beams. Items available for user input are seismic/wind factors, dead, live, and short term loads, a flange on one or both sides, effective slab width, stirrup size, live/short term load combinations, and fixed or pinned end combinations. The center, left, and right sides of the beam can have two rebar sets for both tension and compression reinforcing. Providing detailed strain analysis results to verify moment capacities and shear stirrup spacing requirements at 1/7 points along the beam.

Rectangular Concrete Column

Rectangular Concrete Column determines allowable axial capacities for columns subjected to dead, live, and short term axial loads with bending about one axis. Items considered are unbraced lengths, side sway, effective length factors, and applied point, uniform, and moment loads. Slenderness is evaluated and the necessary moment magnification factors applied to the maximum resultant eccentricities. Reinforcing can be specified in up to five

layer locations, and an exact section analysis based upon internal strains is performed to determine allowable capacity for ACI load combinations 9-1, 9-2 and 9-3.

Circular Concrete Column

Circular Concrete Column determines allowable axial capacities for columns subjected to dead, live, and short term axial loads with bending about one axis. Items considered are unbraced lengths, side sway, effective length factors, and applied point, uniform, and moment loads. Slenderness is evaluated and the necessary moment magnification factors applied to the maximum resultant eccentricities.

Multi Story Shear Wall

Multi Story Shear Wall allows the user to specify a single wall up to five stories high, each portion with different lengths, thicknesses, and materials. Ten lateral and ten vertical dead, live, and short term point loads can be entered, along with lateral weight factors, concrete weight, live/short term combinations, and minimum reinforcing. Total shear, moment, and reinforcing requirements are given for each level with short term loads applied in each direction. A complete footing design is also provided.

Tilt-Up Wall Panel

Tilt-Up Wall Panel gives you extensive analysis capabilities for this popular construction method. You may choose between five common analysis methods which consider deflections, moments, and P-Delta effects. You may apply concentrated or partial length lateral loads to design jambs at openings, and include the effect of negative parapet moment, any degree of base fixity (for dock high walls), and eccentric and concentric vertical loads. The program performs factored and service load calculations to find maximum moments and deflections for any design method. All methods consider P-Delta effects, give detailed section property and cracking data, and give simultaneous analysis results for seismic and wind loading's.

Square Footing Pad Design

Square Footing Pad Design is a workhorse program that provides design for up to six footing per sheet. In addition to dead, live, and short term loads, you may enter seismic zone, overburden, and column size (for 2-way shear). Soil bearing increases for short term loads and for greater depth and width can also be used. Each footing is designed for moment, one-way shear, and punching shear. Reinforcing options for #4 through #10 bars are listed.

General Footing Design

General Footing Design provides detailed uniaxial and biaxial analysis of general rectangular concrete footings. Dead, live, and short term non-concentric axial loads, moments, and shears can be applied about each axis. Short term soil pressure increases, overburden, and column dimensions can be entered. Each recalculation solves for static and short term soil pressures, stability ratios, and factored load moments, one-way shear, and punching shear. The biaxial analysis uses skew bending theory correlated with Esling's studies for pressure under non-tensile sections.

Combined Footing Design

Combined Footing Design allows two independent columns to apply axial, shear and moment loading's along the center line of a rectangular footing. Each column has its own dead, live, and short term load, dimensions, and location. The footing may also have applied overburden, duration of load factor, minimum steel, and seismic/wind factors. Each recalculation evaluates static and short term service soil pressure, stability ratios, factored load moments, one-way shear, punching shear, and reinforcing requirements for all ACI load combinations.

Rebar Embedment length Calculation

Rebar Embedment length calculates the required straight tension, straight compression, and hooked embedment length requirements for reinforcing steel in concrete using the various modification factors allowed by ACI 318-02.

2.1 Multi Span Concrete Beam

This program provides analysis of simple span or continuous concrete beams. The program allows you to design concrete beams in production line form, letting you rapidly complete many designs simultaneously. The program can handle up to eight spans at once. The end fixities of each can easily be modified to model many types of beams, including (but not limited to):

- Simple span beams with cantilevers at one or both ends.
- Single span beams with fixed and/or free ends.
- Continuous beams with up to nine supports.
- Continuous beams with one or both ends pinned, fixed, or cantilevered.

This flexibility is provided by allowing you to:

- Set a flag telling the program to either consider all beams that have pinned ends to be continuous over the support (hooked to the adjacent beam) or consider each span as simply supported.
- For each beam, you can specify fixed, pinned, or free support conditions for each end. This allows you to model any type of span support condition you will encounter (limited to eight spans/nine supports).
- Each span can be loaded with a uniform load, a partial length uniform load, partial length trapezoidal load, up to four point loads, and one concentrated moment. All of these loads can have dead and live components. To further aid your designing ability, you can easily cancel the inclusion of live loads on any span, to perform alternate span load analysis.
- Each span can have top and bottom reinforcing placed at the center and at each end. Shear stirrup spacing is also given for six locations on each span. For each span, the program determines maximum center and support moments, shears, reactions and deflections.

ENERCALC c:\EC55\EXAMPLES.ECIV - Multi-Span Concrete Beam

Multi-Span Concrete Beam

Tools & Settings Help Print Cancel Save

Gener #1 #2 #3 #4 #5 #6 #7 #8

Results Sketch Diagrams Printing

Span Description **Span 1**

Span 17.250 ft

Beam Depth 32.000 in

Beam Width 18.000 in

Left Fixity : Pinned - Right Fixity : Pinned -

Reinforcing... Area "d" depth

Center ... MaxAs= 8.37 in2 4.74 in2 29.00 in

Left ... MaxAs= 0.00 in2 0.00 in2 0.00 in

Right ... MaxAs= 8.37 in2 4.74 in2 3.00 in

Service Loads... Apply Live Load

	Dead Load	Live Load		
Full Length	1.750 k/ft	1.450 k/ft	Start	0.00 ft
Partial			End	0.00 ft
Trapezoidal			Start	0.00 ft
@ Left	0.850 k/ft		End	8.00 ft
@ Right				
			Location	
Point Ld #1	6.500 k			8.00 ft
Point Ld #2	4.750 k			2.75 ft
Point Ld #3				0.00 ft
Point Ld #4				0.00 ft
Moment				0.00 ft

Beam is OK

Moments...

Mu: max @ Mid-Span 6.0 k-ft @ 1.84 ft

Mn * Phi 562.4 k-ft

Mu: max @ Left End 0.0 k-ft

Mn * Phi 0.0 k-ft

Mu: max @ Right End -502.0 k-ft

Mn * Phi 562.4 k-ft

Shear @ Support

Vu @ Left End 6.52 k

Vu @ Right End 56.25 k

Max. Deflection 0.082 in @ 11.27 ft

1: Effective 22,767.80 in4

Reactions... @Left @Right

Dead 15.20 k 64.28 k

Live -8.68 k 40.06 k

Total 6.52 k 104.34 k

Total Factored 6.52 k 158.09 k

Effective Stirrup Rebar Area 0.60 in

Spacing Req'd @ Left n/a in

Spacing Req'd @ .2*L n/a in

Spacing Req'd @ .4*L n/a in

Spacing Req'd @ .6*L 14.50 in

Spacing Req'd @ .8*L 14.50 in

Spacing Req'd @ Right 14.50 in

Basic Usage

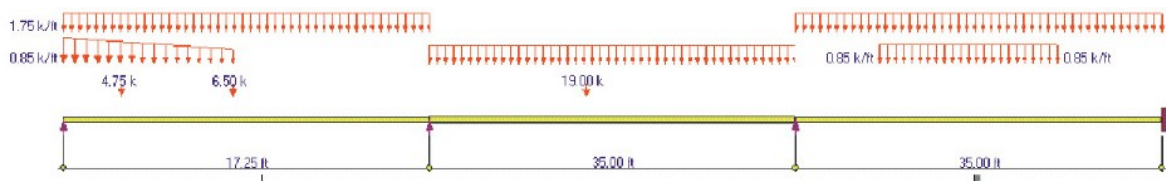
- Review Scope of Design/Analysis Task. It is essential that you fully understand the use of this program, since its flexibility is the key to your rapid design of multi-span concrete members. Remember that each worksheet column represents a single span between two supports, regardless of the end support conditions. When cantilevers are used, they are considered a span, even though one end is free.
- After you've reviewed the beams you wish to design and how they will be entered using the programs All Spans Continuous and end fixity flags, enter this information in the top section of the worksheet. Remember, when you recalculate the worksheet later to get the results, you can always revise the support fixity data to change any mistakes you might have made.
- You can apply up to three distributed loads to each span. Although three loads total are allowed, the input for each is somewhat different. The UNIFORM item applies dead and live loads to the full span. The FIRST DISTRIBUTED load applies a uniform magnitude dead and live load over all or a portion of the span. The SECOND DISTRIBUTED load allows you to specify a trapezoidal load to any portion of the span.
- Point and moment dead and live loads can be applied anywhere on each span. Loads with negative X-distances, or distances that are longer than the span are ignored.
- Modify beam sizes & reinforcing. To refine your design, type in new beam sizes, and review the stresses and deflections.

Unique Features

- A simple flag can be set on any span to ignore all live loads on that span, making alternate span loading analysis easy.
- Very flexible loadings may be applied to each span, including three uniform/partial/trapezoidal loads.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	
Description 3 Span System, 2 Load Patterns									
Operating Mode <input type="radio"/> All Spans Considered as Individual Beams <input checked="" type="radio"/> Spans Considered Continuous Over Supports									
Fy	60,000.0						psi		
fc	3,000.0						psi		
Stirrup Fy	40,000.0						psi		
ACI Dead Load Factor	1.40								
ACI Live Load Factor	1.70								

Operating Mode

This item plays a critical role in governing the calculation procedure for the entire program.

- **Spans Considered Continuous Over Support** : When two beams share the same support , and the support fixity for both beams at that support is Pinned, then the two beams are tied together to form one continuous beam over that support.
- **All Spans Considered as Individual Beams** : When two beams share the same support , they are always considered as two separate beams and the stresses and rotations in one never affect the other.

Within each beam span information tab there is a setting for end fixity. Here is how those end fixities are described according to the selection for this item:

When "**All Spans Considered as Individual Beams**" is chosen:

- Free will indicate that the end is completely free of the support and adjacent beam.
- Pinned will affect the beam according to the end fixity of the adjacent beam. If the adjacent beam end is Fixed or Free, then the beam will be pinned and not affected by the adjacent beam. If the adjacent beam is pinned, the two beams are locked together, forming one beam continuous over the support.

- Fixed will attach the beam end to a rigid boundary element, allowing no rotation or vertical movement, and not linked to the adjacent beam.

When "**Spans Considered Continuous Over Support**" is chosen :

- Free will indicate that the end is completely free of the support, allowing translation and rotation.
- Pinned will allow the beam end to rotate but not translate.
- Fixed will attach the beam end to a rigid boundary element, allowing no rotation or vertical movement.

F_y

Yield strength of reinforcing steel.

f'_c

Compressive strength of concrete.

Stirrup F_y

Yield strength for the stirrup to be designed.

ACI Dead Load Factor

Load factor to be applied to entered dead loads for calculating ultimate moments & shears.

ACI Live Load Factor

Load factor to be applied to entered live loads for calculating ultimate moments & shears.

Typical Span Tab : #1 to #8

Each tab that shows #1 through #8 specifies information for one of the beams of the multi-span beam. Tab #1 is the left-most beam and you work to the right to define additional adjacent spans.

Generals	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8
Span Description		Span 1						
Span		17.250				ft		
Beam Depth		32.000				in		
Beam Width		18.000				in		
Left Fixity :		Free		Right Fixity :		Pinned		
Reinforcing...		<u>Area</u>		<u>"d" depth</u>				
Center . . .	MaxAs=	0.00 in2		0.00		in		
Left	MaxAs=	0.00 in2		0.00		in		
Right	MaxAs=	8.37 in2		2.00		in		
Service Loads...		Apply Live Load		<input type="checkbox"/>				
		<u>Dead Load</u>		<u>Live Load</u>				
Full Length		1.750		1.450		k/ft		
Partial						Start		0.00
						End		0.00
Trapezoidal						Start		0.00
@ Left		0.850				End		8.00
@ Right						Location		
Point Ld #1		6.500				8.00		ft
Point Ld #2		4.750				2.75		ft
Point Ld #3						0.00		ft
Point Ld #4						0.00		ft
Moment						0.00		ft

Span Description

Enter a brief description of this span. Leaving it blank is fine.

Span

This equals the span distance of a beam segment.

Beam Depth

Enter the beam depth for this span. Typically this depth will be the same for all spans when designing a beam continuous over several spans.

Beam Width

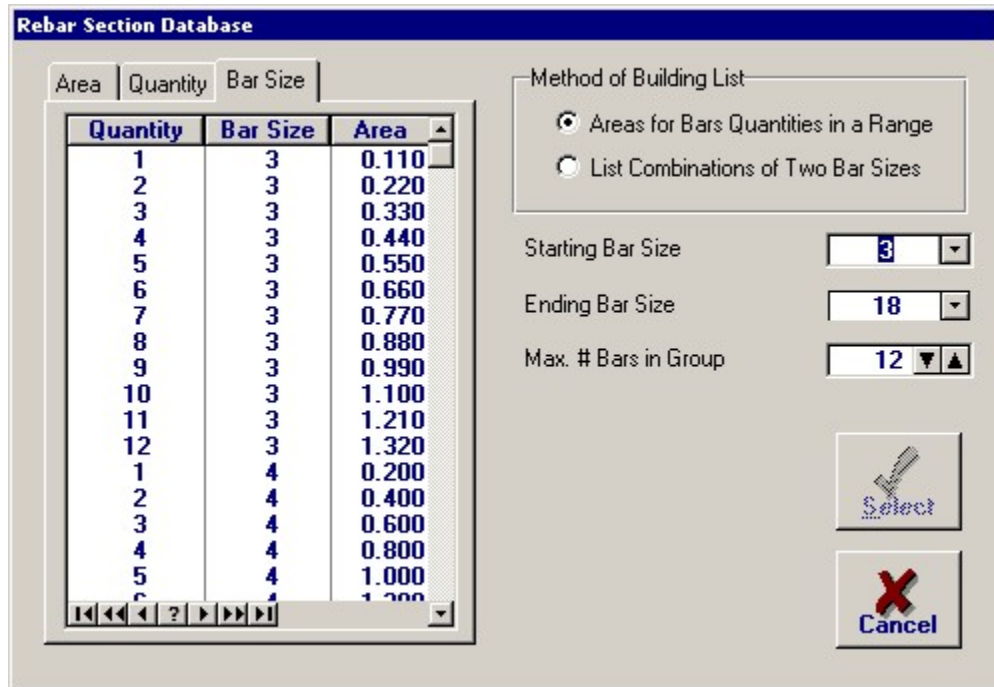
Enter the beam width for this span. Typically this depth will be the same for all spans when designing a beam continuous over several spans.

Left Fixity, Right Fixity

Specifies how the ends of the beam will be restrained.

Reinforcing

Here you enter the reinforcing area and "d" distance from the TOP OF THE BEAM to the C.G. of the reinforcing. Because of space limitations on this tab you need to enter the reinforcing area. You can use the built-in **Rebar Area Calculator** by pressing the "**Tools & Settings**" button at the top of the screen, select "**Databases**" from the pop-up menu, then select "**Rebar**". It will display the following window:



Using this window you can create lists of rebar size & quantity, select a range of sizes to list, and sort the resulting list by Area, Quantity, or Bar Size. This will let you easily create bar set designs as you refine your design.

Apply Live Load This Span?

This entry controls whether or not the live load entered for the span will be used or ignored. A YES/NO entry here gives you a simple way to try various live load alternates to determine maximum moments and shears on multi-span beams.

Applied Loads Tab

Uniform

Uniform dead and live load applied to the entire length of the center span. You should be aware that beam weight is not considered in the program, therefore this input should include allowance for beam weight. These values may be positive or negative.

Partial Length Distributed

Uniform dead and live load applied over a full or partial length of the center span. X-Left indicates the distance from the left support to the beginning of the load, and X-Right is the distance from the left support to the right end of the load. These values may be positive or negative.

Trapezoidal Distributed

Uniform or varying dead and live load applied over a full or partial length of the center span. DL/LL @ Left indicates the dead or live load magnitude at the X-Left distance location. DL/LL @ Right indicates the dead or live load magnitude at the X-Right distance location. These values may be positive,

negative, or both. X-Left indicates the distance from the left support to the beginning of the load, and X-Right is the distance from the left support to the right end of the load.

Point Load

Concentrated dead and live load applied to the beam.

Moment

Dead and live moment applied to the beam.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results Tab

Results	Sketch	Diagrams	Printing
Beam is OK			
Moments...			
Mu: max. @ Mid-Span	6.0 k-ft	@	1.84 ft
Mn * Phi			552.4 k-ft
Mu: max @ Left End			0.0 k-ft
Mn * Phi			0.0 k-ft
Mu: max @ Right End			-502.0 k-ft
Mn * Phi			552.4 k-ft
Shear @ Support			
Vu @ Left End			6.52 k
Vu @ Right End			56.25 k
Max. Deflection			
	0.082 in	@	11.27 ft
I : Effective			22,787.80 in ⁴
Reactions...			
	<u>@Left</u>		<u>@Right</u>
Dead	15.20 k		64.28 k
Live	-8.68 k		40.06 k
Total	6.52 k		104.34 k
Total Factored	6.52 k		158.09 k
Effective Stirrup Rebar Area			
			<input type="text" value="0.60"/> in
Spacing Req'd @ Left			n/a in
Spacing Req'd @ .2*L			n/a in
Spacing Req'd @ .4*L			n/a in
Spacing Req'd @ .6*L			14.50 in
Spacing Req'd @ .8*L			14.50 in
Spacing Req'd @ Right			14.50 in

Mu @ Left, Center, & Right

This is the maximum moment calculated between the supports and at the cantilevers. Since only dead and live loads can be applied, this moment represents only ACI load combination 9-1.

Mn * Phi @ Left, Center, & Right

This is the allowable moment capacity of the beam at the left, center, and right end, considering beam size and positive and negative reinforcing, multiplied by 0.9.

The user must determine the extent to which each set of reinforcing bars must extend past the point of maximum moment.

Shear @ Supports

The factored load shears are given for each end of the beam.

Reactions

The end reactions are calculated using the specified loading, spans, end fixities, and moment distribution results.

Maximum Deflection @ Mid-Span

Using the applied loads, support fixities, and moment distributions results; the resulting deflection curve at 250 points along the beam is searched for the maximum deflection and location. This is the Maximum deflection magnitude, considering both upward and downward displacements. I-effective is determined using ACI equation 9-7 is used.

Effective Stirrup Rebar Area

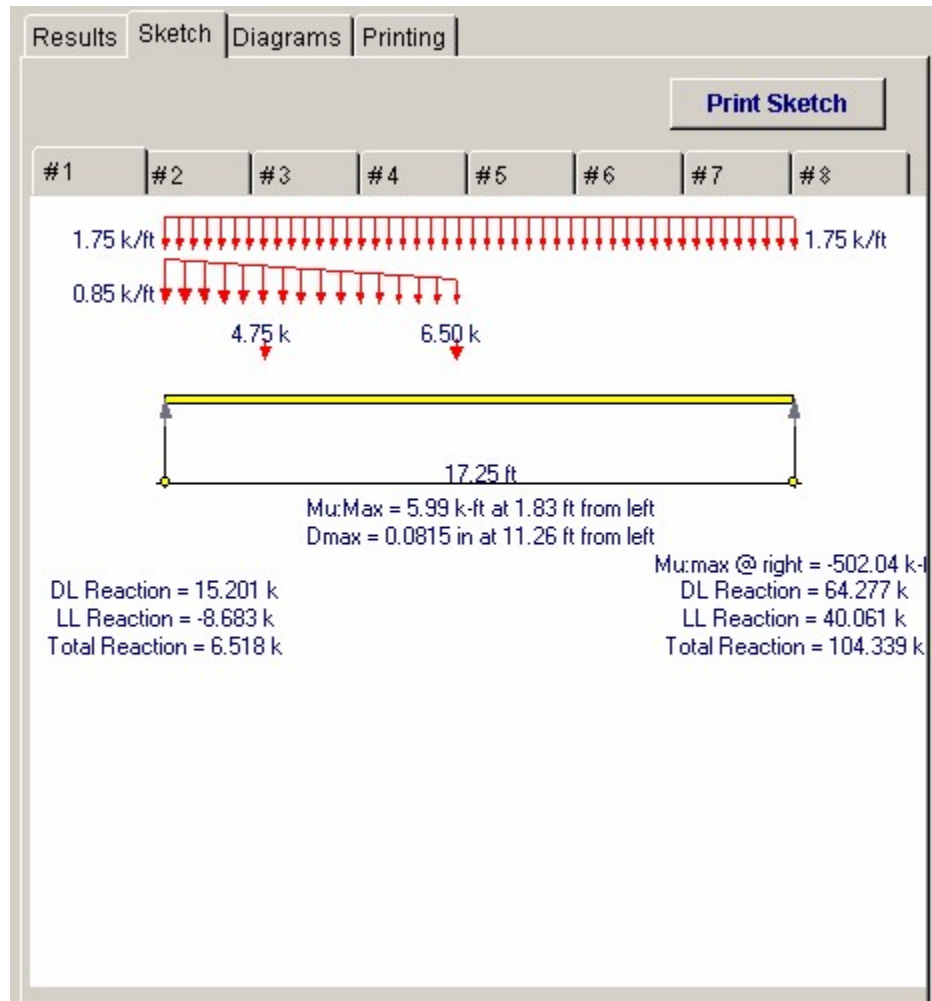
Enter the area for each stirrup. This area will be used to calculate the required stirrup spacing in the section below. For example, if you are using # 3 stirrups, enter $2 * .11 = 0.22$ in².

Stirrup Spacing List

This area displays the minimum required shear stirrup spacing for six equal length zones along the beam span length. When 999" appears on-screen, that indicates that stirrups are not required.

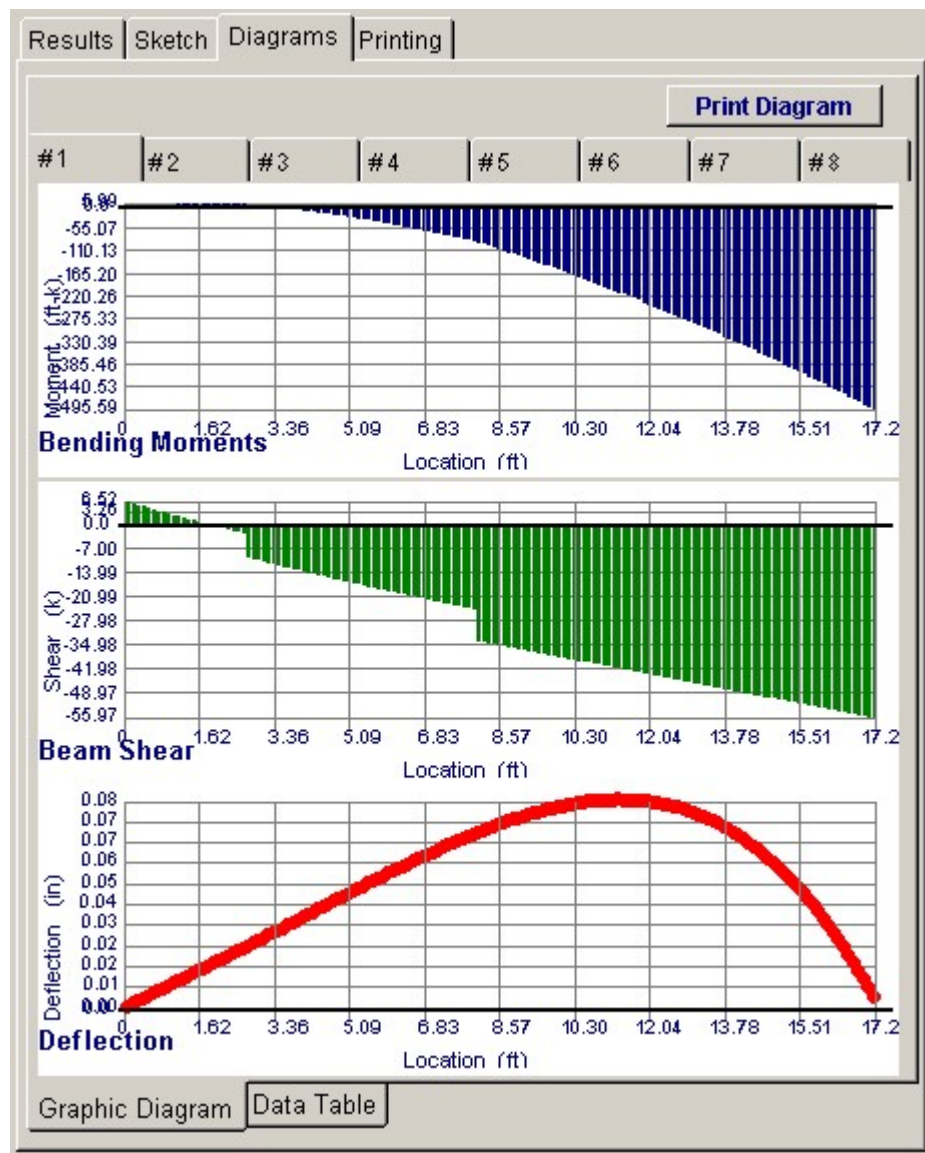
Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Diagrams Tab

This displays a moment, shear, and deflection diagram for the beam with the applied loads and end conditions. Note the two tabs...."Graphic Diagram" and "Data Table". The Data Table tab provides the entire internal analysis at the 1/500th points within the beam.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Diagrams | Printing

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Concrete Member Information	<input checked="" type="checkbox"/>
Loads	<input checked="" type="checkbox"/>
Results	<input checked="" type="checkbox"/>
Reactions & Deflections	<input checked="" type="checkbox"/>
Shear Stirrups	<input checked="" type="checkbox"/>
Query Values	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
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 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title : ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 10:37PM, 26 OCT 03
 Description : Collection of example problems
 Scope : All programs in the Structural Engineering Library

Rev: 980000
 User: KVA0000001, Ver 5.8.0, 10-Sep-2003
 (c)1983-2003 ENERCALC Engineering Software

Multi-Span Concrete Beam

Page 1

c:\e05\example.socw\Concrete Calc

Description 3 Span System, 2 Load Patterns

General Information

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Fy	60,000.0 psi	Spans Considered	Continuous Over Supports	ACI Dead Load Factor	1.40
fc	3,000.0 psi	Stirrup Fy	40,000.0 psi	ACI Live Load Factor	1.70

Concrete Member Information

Description	Span 1	Span 2	Span 3			
Span	17.25	35.00	35.00	8.00	35.00	35.00
Beam Width	18.00	18.00	18.00	18.00	0.00	18.00
Beam Depth	32.00	32.00	32.00	32.00	0.00	32.00
End Fixity	Free-Pin	Pin-Pin	Pin-Fix	Free-Pin	Free-Free	Pin-Fix
Reinforcing	Center	Area	5.00in2	2.00in2		2.00in2
	Bar	Depth	29.00in	29.00in		29.00in
	Left	Area	2.00in2	5.00in2		5.00in2
	Bar	Depth	3.00in	3.00in		3.00in
	Right	Area	2.00in2	3.00in2	2.00in2	3.00in2
	Bar	Depth	3.00in	3.00in	3.00in	3.00in

Loads

Using Live Load This Span ??	No	Yes	No	Yes	No	Yes
Dead Load	k/ft	1.750	1.750	1.750	1.750	1.750
Live Load	k/ft	1.450	1.450	1.450	1.450	1.450
Dead Load	k/ft			0.850		0.850
Live Load	k/ft			0.650		0.650
Start	ft	0.000	0.000	8.000	0.000	0.000
End	ft	0.000	0.000	25.000	0.000	25.000
DL @ Left	k/ft	0.850		0.850		
DL @ Right	k/ft					
LL @ Left	k/ft					
LL @ Right	k/ft					
Start	ft	0.000	0.000	0.000	0.000	0.000
End	ft	8.000	0.000	0.000	8.000	0.000
Point #1 DL	k	6.500	10.250			
LL	k		8.750			
@ X	ft	8.000	15.000	0.000	0.000	0.000
Point #2 DL	k	4.750				
LL	k					
@ X	ft	2.750	0.000	0.000	0.000	0.000

Results

	Overstress	Overstress	Beam OK	Beam OK	Beam OK	Overstress
Mmax @ Cntr	k-ft	0.00	423.07	142.06	0.00	0.00
@ X =	ft	0.00	15.63	19.37	0.00	35.00
Mn * Phi	k-ft	0.00	578.85	249.21	0.00	0.00
Max @ Left End	k-ft	0.00	-614.52	-500.39	0.00	0.00
Mn * Phi	k-ft	0.00	249.21	578.85	0.00	0.00
Max @ Right End	k-ft	-614.53	-500.39	-244.92	-182.67	0.00
Mn * Phi	k-ft	249.21	578.85	364.90	249.21	0.00
		Bending NG	Bending NG	Bending OK	Bending OK	Bending NG
Shear @ Left	k	0.00	105.97	60.87	0.00	0.00
Shear @ Right	k	62.77	95.28	45.11	44.08	0.00

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems **Job #** 97-000001
Dsgnr: MDB **Date:** 10:37PM, 26 OCT 03
Description: Collection of example problems
Scope: All programs in the Structural Engineering Library

Rev: 080000
 User: RW-0000001, Ver 5.8.0, 10-Sep-2003
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Multi-Span Concrete Beam

Page 2
e:\e05\examples.sdw\Concrete Calc

Description 3 Span System, 2 Load Patterns

Reactions & Deflections

DL @ Left	k	0.00	89.11	62.51	0.00	0.00	38.42
LL @ Left	k	0.00	25.88	40.37	0.00	0.00	31.34
Total @ Left	k	0.00	114.99	102.88	0.00	0.00	69.76
DL @ Right	k	89.11	62.51	40.42	17.40	0.00	37.28
LL @ Right	k	25.88	40.37	-6.75	11.60	0.00	30.46
Total @ Right	k	114.99	102.88	33.67	29.00	0.00	67.74
Max. Deflection	in	0.083	-0.493	-0.286	0.000	0.000	-0.819
@ X =	ft	0.00	17.73	19.13	0.00	0.00	17.50
Inertia : Effective	in4	0.00	23,127.91	12,349.39	0.00	0.00	11,584.75

Shear Stirrups

Stirrup Rebar Area	in2	0.600	0.600	0.600	0.600	0.000	0.600
Spacing @ Left	in	Not Req'd	12.89	14.50	Not Req'd	0.00	12.59
Spacing @ .2*L	in	Not Req'd	14.50	14.50	Not Req'd	0.00	14.50
Spacing @ .4*L	in	14.50	14.50	Not Req'd	Not Req'd	0.00	14.50
Spacing @ .6*L	in	14.50	14.50	Not Req'd	14.50	0.00	14.50
Spacing @ .8*L	in	14.50	14.50	14.50	14.50	0.00	14.50
Spacing @ Right	in	14.50	14.50	14.50	14.50	0.00	13.47

Query Values

Location	ft	4.00	0.00	0.00	0.00	0.00	0.00
Moment	k-ft	-34.1	-614.5	-500.4	0.0	0.0	-665.9
Shear	k	-19.7	106.0	60.9	0.0	0.0	107.1
Deflection	in	0.1276	0.0000	0.0000	0.0000	0.0000	0.0000

2.2 Concrete Beam

This program provides design analysis of single span concrete beams with a variety of end restraints, bar placements, and loading conditions.

This program is intended to provide more detailed analysis capability for a single span beam than the Multi-Span program. The Multi-Span program should be used to rapidly design multi-span beams or many simple or cantilevered beams.

Either a rectangular or T type beam can be analyzed by this program. Both types can have reinforcing located at the top and bottom of each end and in the center. All three of these locations can have two layers of top and two layers of bottom reinforcing specified.

The program also supports a variety of end fixities; Fix/Fix, Pin/Pin, Fix/Pin, and Pin/Fix. If cantilevers are needed, you will have to use the Multi-Span beam program. With this variety of reinforcing locations and end fixities, almost any type of concrete beam can be analyzed.

Up to twelve loads can be applied to the beam. These include:

- ▶ Up to five full or partial length uniform loads with dead, live, and short term components.
- ▶ Up to five point loads with dead, live, and short term components.
- ▶ Two applied moments with dead, live, and short term components.

Each recalculation of the program evaluates shears, moments, and deflections for ACI load factor combinations 9-1, 9-2, and 9-3. The concrete section analysis conforms to ACI and UBC codes. This includes the additional load factoring requirements for Seismic Zone 3 and 4, specified in UBC section 2625.

Additional features include; the ability to neglect live loads in combination with short term, optional inclusion of beam weight into applied dead loads, and specification of shear stirrup area ,to create a table of required shear stirrup spacings.

ENERCALC c:\ECSS\EXAMPLES.ECIV - Rectangular & Tee Beam Design

Rectangular & Tee Beam Design

Tools & Settings | ? Help | Design | Print | Cancel | Save

General | Rebar | Uniform Loads | Concentrated Loads | ACI Factors

Results | Sketch | Diagrams | Printing

Summary | Section Analysis | Stirrups/Other

Description Moments @ Each End, + & - reinforcing

Span 30.000 ft

Depth 40.000 in

Width 16.000 in

Flanged Beam Data... (Optional)

Flange Thickness 8.000 in

Web Spacing 8.000 ft

Flanges 1 Side 2 Sides

End Footy

Pinned-Pinned

Fixed-Fixed

Fixed-Pinned

Pinned-Fixed

Fixed-Free

fc 3,000.0 psi

Fy 60,000.0 psi

Concrete Density 145.00 pcf

Seismic Zone 0

Does Live Load act with Short Term?

Auto Calc of Beam Wt?

Tee Beam Weight Calc Method:

Use Rectangular Section Only

Use "Tee" Section with Width = Effective Width

Use "Tee" Section with Width = Web Spacing

Beam Design OK

Maximum Moment : Mu 883.18 k-ft

Allowable Moment : Mn*phi 1,515.41 k-ft

Maximum Shear : Vu 87.36 k

Allowable Shear : Vn*phi 87.36 k

Bending...

	Mn*Phi	Mu, Eq. C-1	Mu, Eq. C-2	Mu, Eq. C-3
@ Center	1,515.41	683.18	260.94	223.67 k-ft
@ Left End	362.70	-214.32	-103.11	-88.36 k-ft
@ Right End	101.05	-0.01	0.00	0.00 k-ft

Shear...

	Vn*Phi	Vu, Eq. C-1	Vu, Eq. C-2	Vu, Eq. C-3
@ Left End	87.36	87.36	35.65	30.56 k
@ Right End	80.28	79.83	30.18	25.87 k

Deflections...

	Upward	Downward
DL+BmWt	0.0000 in at 30.000 ft	-0.094 in at 15.480 ft
DL+LL+BmWt	0.0000 in at 30.000 ft	-0.244 in at 15.480 ft
DL+LL+ST+BmWt	0.0000 in at 30.000 ft	-0.094 in at 15.480 ft

Reactions...

	@ Left	@ Right
DL + [Bm Wt]	39.190 k	33.143 k
DL + LL + [Bm Wt]	65.017 k	64.617 k
DL + LL + ST + [Bm Wt]	39.190 k	33.143 k

Basic Usage

- You must enter the beam span, depth, and width of the beam, however T Flange Thick, Flange Both Sides, and Web Spacing are only used when a Tee type beam is being used. They will be used to determine effective slab width and section properties. Include Bm. Wt is a YES/NO flag that will calculate and add beam weight to the applied dead loads. This is handy when designing large beams with little applied load, as the design size refinements will have the most effect on loading. Stirrup Bar Area indicates the total stirrup area at each stirrup location. This area is used to determine maximum stirrup spacings.
- These items define the material strengths and density, load factoring, and load combinations for the beam. Seismic Zone is used to determine whether applied short term loads are from wind or seismic forces (by entering 0" or non-zero numbers), and also to determine if special load factors for seismic zone 3 and 4 should be used.
- This table provides an easy method to specify reinforcing at any portion of the beam. Center, Left, and Right refer to the location of the reinforcing specified in the two columns below. Each location can have both tension and compression reinforcing by using four available entries to specify rebar depth, size, and quantity. Please note that the d distance (depth) is always measured down from the top of the beam. The column headings Top and Bottom are only for your reference, the actual d distances locate the rebar placement.

- Applied Loads provides entry of point, distributed, and moment loads. The Start and End locations refer to the distance from the left support to the position of start/end of the load.

Unique Features

- All calculations use detailed concrete section analysis routines, which determine exact strain conditions for evaluation of moment capacities.
- This program reduces the typically extensive calculations required for investigation of a doubly reinforced concrete section (with or without T flanges) down to a quick calculation.
- Due to this calculation ability, a section may be quickly designed by a series of WHAT-IF entries for beam size and reinforcing.
- The designer may specify any combination of tension or compression reinforcing. The program will adjust its analysis accordingly.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.

Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General	Rebar	Uniform Loads	Concentrated Loads	ACI Factors
Description Moments @ Each End, + & - reinforcing				
Span	<input type="text" value="30.000"/>	ft	End Fixity	
Depth	<input type="text" value="40.000"/>	in	<input checked="" type="radio"/> Pinned-Pinned	
Width	<input type="text" value="16.000"/>	in	<input type="radio"/> Fixed-Fixed	
Flanged Beam Data... (Optional)				
Flange Thickness	<input type="text" value="8.00"/>	in	<input type="radio"/> Fixed-Pinned	
Web Spacing	<input type="text" value="8.000"/>	ft	<input type="radio"/> Pinned-Fixed	
Flanges	<input type="radio"/> 1 Side <input checked="" type="radio"/> 2 Sides		<input type="radio"/> Fixed-Free	
fc	<input type="text" value="3,000.0"/>	psi		
Fy	<input type="text" value="60,000.0"/>	psi		
Concrete Density	<input type="text" value="145.00"/>	pcf		
Seismic Zone	<input type="text" value="0"/>			
Does Live Load act with Short Term ?			<input type="checkbox"/>	
Auto Calc of Beam Wt ?			<input checked="" type="checkbox"/>	
Tee Beam Weight Calc Method				
<input checked="" type="radio"/> Use Rectangular Section Only				
<input type="radio"/> Use "Tee" Section with Width = Effective Width				
<input type="radio"/> Use "Tee" Section with Width = Web Spacing				

Beam Span, Depth, &Width

These dimensions specify the beam size and length. The span value will be used to calculate moments, shears, and deflections from the applied loads. Depth and width can be modified to design the beam as required.

Flanged Beam Data**Flange Thickness**

This entry specifies the thickness of a T flange at the compression edge of the beam. This entry is optional, and entering zero will mean that a simple rectangular beam is being used. The flange thickness is measured from the top of beam downward (there is no effect on the overall beam depth specified above).

Web Spacing

This item also is only needed when a T type beam is specified, and is used to calculate the effective flange width for the beam, and is the spacing between beams.

Flanges

This item helps the program calculate the effective flange width to be used when a T beam is being

used. When the beam is positioned so that the slab extends to either side answer "2 sides".

f_c

Design concrete strength to be used.

F_y

The yield strength of reinforcing to be used.

Concrete Density

This weight is used when the program has been instructed to calculate beam weight.

Seismic Zone

This item specifies whether the short-term loads are due to wind or seismic forces. Entering a 0" indicates that short-term loads are due to wind. Entering 1" to 4" specifies that the short-term loads come from UBC seismic zone loads. Additionally, when zone 3 and 4 is used, the special load factoring for that zone required by the UBC are used.

Does Live Load act with Short Term ?

This entry controls whether or not live loads are used when ACI load combination 9-2 calculations are executed. When short-term loads are due to wind forces, live loads are typically used, whereas seismic forces usually ignore live load effects (except high storage loads).

Include Beam Weight

This YES/NO item tells the program whether to automatically calculate the beam weight and add the dead load to the bending calculations. The weight of the flange is not calculated.

Tee Beam Weight Calculation Method

- **Use Rectangular Section Only** : Calculates the beam weight using only the Beam Width & Beam Depth dimensions
- **Use "Tee" section with width = Effective Width** : Calculated the beam weight using the width of the "T" section flange equal to the calculated effective width of the flange.
- **Use "Tee" section with Width = Web Spacing** : Calculated the beam weight using the web spacing of the flange.

Rebar Tab

This tab allows you to specify the reinforcing to be used in the beam. The location of the rebar **'d' from Top** is ALWAYS specified as measured from the top of the beam. The program will internally detect whether the surface where there is tension or compression and will use the rebar properly.

	General	Rebar	Uniform Loads	Concentrated Loads	ACI Factors
Rebar @ Center of Beam...					
		<u>C</u> ount	<u>S</u> ize	<u>'d'</u> from Top	
#1		5	9	33.000	in
#2		5	9	37.000	in
#3		5	9	3.000	in
#4			0	0.000	in
Rebar @ Left End of Beam...					
		<u>C</u> ount	<u>S</u> ize	<u>'d'</u> from Top	
#1		2	5	30.000	in
#2			0	0.000	in
#3		3	6	3.000	in
#4		3	5	6.000	in
Rebar @ Right End of Beam...					
		<u>C</u> ount	<u>S</u> ize	<u>'d'</u> from Top	
#1		2	5	30.000	in
#2			0	0.000	in
#3		3	5	3.000	in
#4		3	5	6.000	in

Size & Count

Enter the rebar size # (in 1/8th's of an inch) and quantity for each layer, top and/or bottom, and at the center/ends.

Rebar @ Center of Beam

These entries specify the rebar to be used to resist the maximum moment that will occur between the ends of the beam.

Rebar @ Left and Right End of Beam

These entries specify the rebar to be used to resist the moment at the left end of the beam. If the beam has a "Fixed" end and the tension is in the top of the beam, enter the 'd' distance as just a few inches.

Uniforms Loads Tab

Enter all loads as service loads. Appropriate load factors will be applied internally to calculate ultimate moments & shears (Mu & Vu).

	General	Rebar	Uniform Loads	Concentrated Loads	ACI Factors
Service Distributed Loads...					
			<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
#1			<input type="text" value="1.100"/> k/ft	<input type="text" value="0.000"/> ft	<input type="text" value="30.000"/> ft
			Start	End	
#2			<input type="text" value="0.800"/> k/ft	<input type="text" value="0.000"/> ft	<input type="text" value="24.000"/> ft
			Start	End	
#3			<input type="text" value="0.000"/> k/ft	<input type="text" value="0.000"/> ft	<input type="text" value="0.000"/> ft
			Start	End	
Service Trapezoidal Loads...					
#1			<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
@ Left			<input type="text" value="0.800"/> k/ft	<input type="text" value="24.000"/> ft	<input type="text" value="30.000"/> ft
@ Right			<input type="text" value="3.900"/> k/ft	Start	End
			Start	End	
#2			<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
@ Left			<input type="text" value="0.000"/> k/ft	<input type="text" value="0.000"/> ft	<input type="text" value="0.000"/> ft
@ Right			<input type="text" value="0.000"/> k/ft	Start	End
			Start	End	

Service Distributed Loads

You can enter up to three distributed loads each with dead, live and short term components that can be either full or partial length.

Service Trapezoidal Loads

You can enter up to two trapezoidal loads each with dead, live and short term components that can be either full or partial length.

Concentrated Loads Tab

	General	Rebar	Uniform Loads	Concentrated Loads	ACI Factors
Service Point Loads...					
			<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
#1			<input type="text" value="10.000"/>	<input type="text" value="12.000"/>	<input type="text" value=""/> k
				Location.....	<input type="text" value="10.250"/>
#2			<input type="text" value="10.000"/>	<input type="text" value="12.000"/>	<input type="text" value=""/> k
				Location.....	<input type="text" value="20.500"/>
#3			<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/> k
				Location.....	<input type="text" value="0.000"/>
#4			<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/> k
				Location.....	<input type="text" value="0.000"/>
#5			<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/> k
				Location.....	<input type="text" value="0.000"/>
Service Moment Loads...					
			<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
#1			<input type="text" value="98.200"/>	<input type="text" value="45.200"/>	<input type="text" value=""/> k-ft
				Location.....	<input type="text" value="0.000"/>
#2			<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/> k-ft
				Location.....	<input type="text" value="30.000"/>

ACI Load Factors

This tab specifies the load factors to be used by the program when calculation the factored dead, live, and short term loads to be used in the internal load combinations for determining Mu and Vu for the beam.

General	Rebar	Uniform Loads	Concentrated Loads	ACI Factors
Load Factors (Nomenclature per ACI 318-02, Appx C)				
ACI C-1 && C-2 Dead Load				1.400
ACI C-1 && C-2 Live Load				1.700
ACI C-1 && C-2 Short Term				1.700
....seismic = ST * :				1.100
				<i>used in C-1, C-2, and C-3</i>
ACI C-2 Group Factor				0.750
ACI C-3 Dead Load Factor				0.900
ACI C-3 Short Term Factor				1.300
Additional factors for Seismic Zone 3 & 4				
"1.4" Factor				1.400
"0.9" Factor				0.900

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results / Summary Tab

Results		Sketch	Diagrams	Printing
Summary		Section Analysis	Stirrups/Other	
Beam Design OK				
Maximum Moment : Mu		683.18	k-ft	
Allowable Moment : Mn*phi		1,515.41	k-ft	
Maximum Shear : Vu		87.36	k	
Allowable Shear : Vn*phi		87.36	k	
Bending...	<u>Mn*Phi</u>	<u>Mu, Eq. C-1</u>	<u>Mu, Eq. C-2</u>	<u>Mu, Eq. C-3</u>
@ Center	1,515.41	683.18	260.94	223.67 k-ft
@ Left End	362.70	-214.32	-103.11	-88.38 k-ft
@ Right End	101.05	-0.01	0.00	0.00 k-ft
Shear...	<u>Vn*Phi</u>	<u>Vu, Eq. C-1</u>	<u>Vu, Eq. C-2</u>	<u>Vu, Eq. C-3</u>
@ Left End	87.36	87.36	35.65	30.56 k
@ Right End	80.28	79.83	30.18	25.87 k
Deflections...	<u>Upward</u>		<u>Downward</u>	
DL+BmWt	0.0000 in	at 30.000 ft	-0.094 in	at 15.480 ft
DL+LL+BmWt	0.0000 in	at 30.000 ft	-0.244 in	at 15.480 ft
DL+LL+ST+BmWt	0.0000 in	at 30.000 ft	-0.094 in	at 15.480 ft
Reactions...	<u>@ Left</u>		<u>@ Right</u>	
DL + [Bm Wt]	39.190 k		33.143 k	
DL + LL + [Bm Wt]	65.017 k		64.617 k	
DL + LL + ST + [Bm Wt]	39.190 k		33.143 k	

Maximum Values

Mu

Actual moments due to ACI load combinations 9-1, 9-2, and 9-3 are listed here for the center and end of the beam.

Mn * Phi

Maximum moment capacity at the center and ends of the beam based upon beam size, reinforcing, and material strengths. To determine section capacity, a detailed static analysis of the strain conditions within the beam is executed, with minimum and maximum rebar percentages checked. When compression reinforcing has been specified, the section is still checked for ductile failure (tension steel yield). These moments are multiplied by: $\Phi = 0.9$.

Vu

Actual shear at each end is given here based upon applying ACI load factor combinations 9-1, 9-2, and 9-3. Shear is calculated at a distance d from the support.

Vn * Phi

The shear capacity at each end of the member is calculated using the beam dimensions and the minimum shear stirrup spacing calculated for the specified shear stirrup area.

Bending Summary

This area of calculated values gives the allowable moment and factored load moment at each of the three analysis locations. The reference to "C-1", "C-2", and "C-3" are to the ACI factoring load combinations that were run to get the results

Shear Summary

This area of calculated values gives the allowable moment and factored load moment at each of the three analysis locations. The reference to "C-1", "C-2", and "C-3" are to the ACI factoring load combinations that were run to get the results

Deflections

Deflections are listed for two combinations of service loads, which represent static and short-term load combinations. These are instantaneous deflections using ACI equation 9-7. Both upward and downward deflections and the locations at which they occur are given. If any non-zero entry in the Location entry under Additional Deflection Data has been entered, all deflections are listed for that point. Otherwise, 250 span increments are evaluated for maximum and minimum values.

Reactions

Reactions are listed for two combinations of service loads, which represent the static and short-term combinations.

Results / Section Analysis Tab

For the center area, left end and right end all of the critical values developed in the analysis of the concrete section you have specified are given.

Results Sketch Diagrams Printing			
Summary Section Analysis Stirrups/Other			
Evaluate Moment Capacity...	<u>Center</u>	<u>Left</u>	<u>Right</u>
X : Neutral Axis	3.080	4.965	2.825
a = beta * Xneutral	2.618	4.220	2.401
Compression in Concrete	106.814	172.186	97.971
Sum [Steel comp. forces]	0.000	0.000	0.000
Tension in Reinforcing	-601.451	-172.200	-98.012
Find Max As for Ductile Failure...			
X-Balanced	21.898	21.898	17.7551
Xmax = Xbal * 0.75	16.423	16.423	13.3163
a-max = beta * Xbal	18.613	18.613	15.0918
Compression in Concrete	2,079.166	569.566	461.810
Sum [Steel Comp Forces]	287.250	19.516	95.511
Total Compressive Force	2,366.416	589.082	557.321
AS Max = Tot Force / Fy	39.440	9.818	9.2887
Actual Tension As	10.000	2.870	2.480
	OK	OK	OK

Results / Stirrups Tab

This section lists minimum stirrup spacings at seven divisions along the beam length. Shear provisions of ACI section 11.3, 11.4, and 11.5 are evaluated using the Shear Area entered in the section titled Beam Data.

Results Sketch Diagrams Printing		
Summary Section Analysis Stirrups/Other		
Stirrup Area @ Cross Section		<input type="text" value="0.220"/> in ²
Region	Max. Stirrup Spacing in region	Max Vu in region
0.00 ft	12.876 in	87.365 k
5.00 ft	16.500 in	80.064 k
10.00 ft	16.500 in	60.901 k
15.00 ft	16.500 in	11.369 k
20.00 ft	Not Req'd in	11.369 k
25.00 ft	16.500 in	65.337 k
30.00 ft	16.500 in	79.832 k
<hr/>		
Neutral Axis		7.270 in
I _{gross}		167218.98 in ⁴
I _{cracked}		84,172.56 in ⁴
Elastic Modulus		3,122.0 psi
$F_r = 7.5 * f_c^{.5}$		410.792 ksi
Z:Cracking (ACI 10.6.4)		83.108 k/in
Eff. Flange Width		90.00 in
M _{cr}		206.74 k-ft
M _s :Max DL + LL		445.71 k-ft
$R1 = (M_s:DL+LL)/M_{cr}$		0.464
M _s :Max DL+LL+ST		248.46 k-ft
$R2 = (M_s:DL+LL+ST)/M_{cr}$		0.832
I:eff... M _s (DL+LL)		92,460.739 in ⁴
I:eff... M _s (DL+LL+ST)		132019.325 in ⁴

Stirrup Area @ Cross Section

Enter the cross sectional area of the stirrups to be used for the calculation of stirrup spacing. For example, if you are using #3 stirrups there will be two vertical legs capable of resisting shear so the area to enter is $0.11 \text{ sq. in} * 2 \text{ legs} = 0.22 \text{ in}^2$.

The table gives the stirrup spacing requirements for various regions of the beam divided up into equal length increments. The maximum stirrup spacing and the actual shear in that area (the maximum) is given.

If the spacing shows as "999" then the shear is below code limits and stirrups are not required for shear (but might be to satisfy minimum reinforcing requirements).

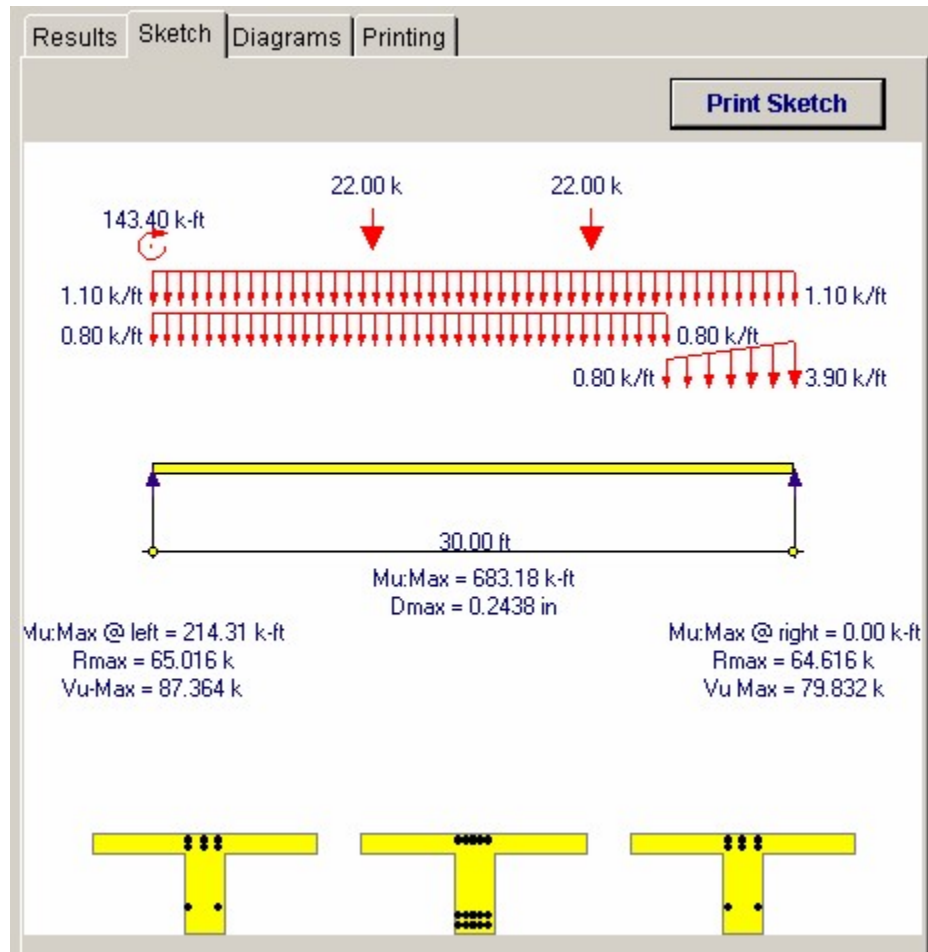
Additional Deflection Values

This section gives additional details of the values calculated in the program for use in calculating section properties and values for deflection

Sketch Tab

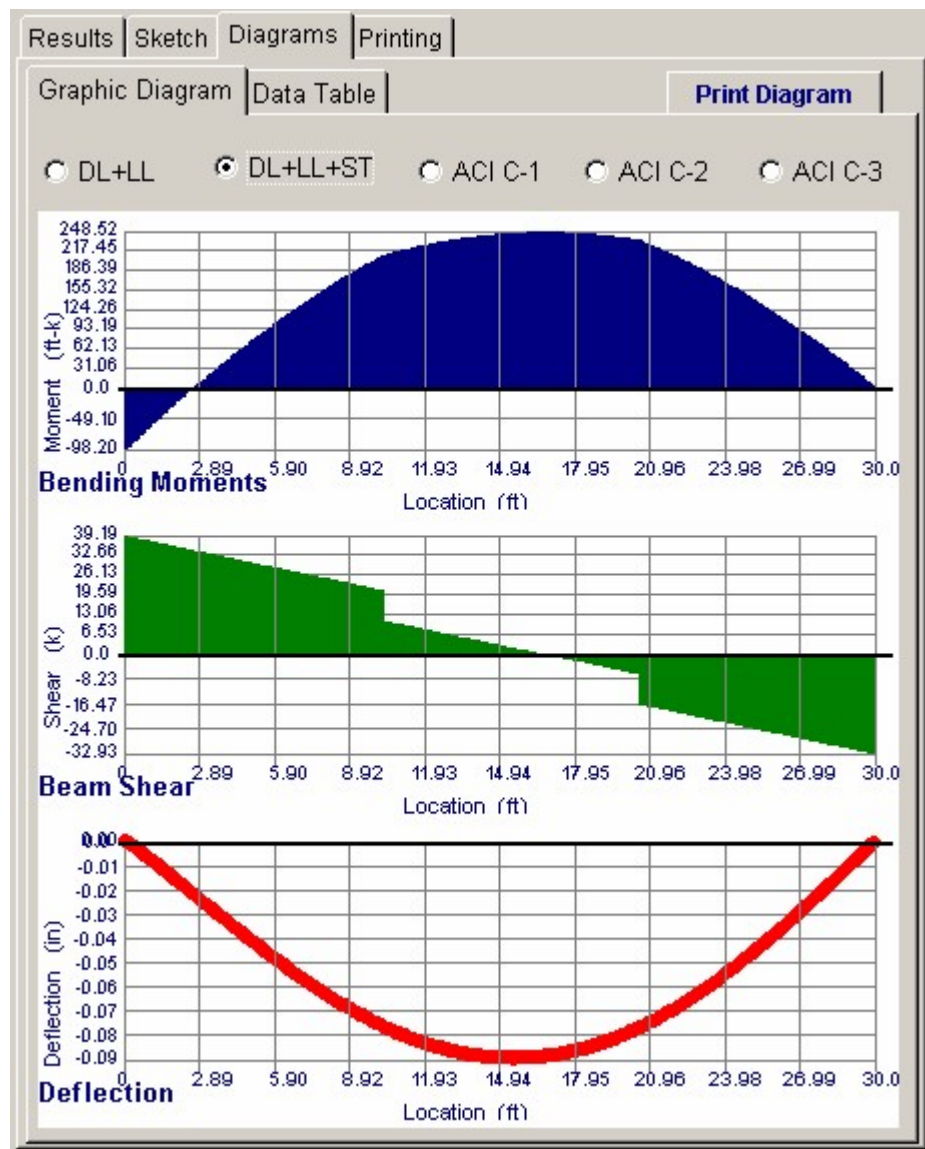
This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print

Sketch] button will print the sketch in large scale on a single sheet of paper.



Diagrams Tab

This displays a moment, shear, and deflection diagram for the beam with the applied loads and end conditions. Note the two tabs...."Graphic Diagram" and "Data Table". The Data Table tab provides the entire internal analysis at the 1/500th points within the beam.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Diagrams | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Reinforcing	<input checked="" type="checkbox"/>
Uniform Loads	<input checked="" type="checkbox"/>
Trapezoidal Loads	<input checked="" type="checkbox"/>
Concentrated Loads	<input checked="" type="checkbox"/>
Moments	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Bending & Shear Force Summary	<input checked="" type="checkbox"/>
Deflection	<input checked="" type="checkbox"/>
Section Analysis	<input checked="" type="checkbox"/>
Additional Deflection Calcs	<input checked="" type="checkbox"/>
ACI Factors	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
P.O. Box 188
Corona del Mar, CA 92660
Voice: 949-645-0151
www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
Dsgnr: MDB Date: 10:43PM, 26 OCT 03
Description: Collection of example problems

44 programs in the Structural Engineering Library

Rev: 080000
User: HW0000001, Ver 5.8.0, 10-Sep-2003
(c)1983-2003 ENERCALC Engineering Software

Concrete Rectangular & Tee Beam Design

Page 1
c:\ecdf\examples.eaw Concrete Calc

Description Moments @ Each End, + & - reinforcing

General Information

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Span	30.00 ft	f _c	3,000 psi
Depth	40.000 in	F _y	60,000 psi
Width	16.000 in	Concrete Wt.	145.0 pcf
Flange @ Both Sides		Seismic Zone	0
Flange Thickness	8.000 in	End Fkty	Pinned-Pinned
Web Spacing	8.000 ft	Live Load not acting with Short Term	
Tee beam weight calc'd using Depth * Width			

Reinforcing

Rebar @ Center of Beam..				Rebar @ Left End of Beam..				Rebar @ Right End of Beam..			
	Count	Size	'd' from Top		Count	Size	'd' from Top		Count	Size	'd' from Top
#1	5	9	33.00 in	#1	2	5	30.00 in	#1	2	5	30.00 in
#2	5	9	37.00 in	#2			in	#2			in
#3	5	9	3.00 in	#3	3	6	3.00 in	#3	3	5	3.00 in
#4			in	#4	3	5	6.00 in	#4	3	5	6.00 in

Load Factoring

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design.
Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

Uniform Loads

	Dead Load	Live Load	Short Term	Start	End
#1	1.100 k	k	k	0.000 ft	30.000 ft
#2	k	0.800 k	k	0.000 ft	24.000 ft

Trapezoidal Loads

	DL @ Left	k/ft	LL @ Left	0.800 k/ft	ST @ Left	k/ft	Start	24.000 ft
#1	DL @ Right	k/ft	LL @ Right	3.900 k/ft	ST @ Right	k/ft	End	30.000 ft

Concentrated Loads

	Dead Load	Live Load	Short Term	Location
#1	10.000 k	12.000 k	k	10.250 ft
#2	10.000 k	12.000 k	k	20.500 ft

Moments

	Dead Load	Live Load	Short Term	Location
#1	98.200 k-ft	45.200 k-ft	k-ft	0.000 ft
#2	k-ft	k-ft	k-ft	30.000 ft

Summary

Beam Design OK

Span = 30.00ft, Width= 16.00in Depth = 40.00in T Beam with Flange= 8.00in thick @ Both Sides, Web spac= 8.00ft

Maximum Moment : Mu	683.18 k-ft	Maximum Deflection	-0.2439 in
Allowable Moment : Mn*phi	1,515.41 k-ft		
Maximum Shear : Vu	87.36 k	Max Reaction @ Left	65.02 k
Allowable Shear : Vn*phi	87.36 k	Max Reaction @ Right	64.62 k

Shear Stirrups...

Stirup Area @ Section	0.220 in ²						
Region	0.000	5.000	10.000	15.000	20.000	25.000	30.000 ft
Max. Spacing	12.876	16.500	16.500	16.500	Not Req'd	16.500	16.500 in
Max Vu	87.365	80.064	60.901	11.369	11.369	65.337	79.832 k

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Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 10:43PM, 26 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Description Moments @ Each End, + & - reinforcing

Bending & Shear Force Summary

Bending...	Mn *Phi	Mu, Eq. C-1	Mu, Eq. C-2	Mu, Eq. C-3
@ Center	1,515.41 k-ft	683.16 k-ft	260.94 k-ft	223.67 k-ft
@ Left End	362.70 k-ft	-214.32 k-ft	-103.11 k-ft	-88.38 k-ft
@ Right End	101.05 k-ft	-0.01 k-ft	0.00 k-ft	0.00 k-ft
Shear...	Vn *Phi	Vu, Eq. C-1	Vu, Eq. C-2	Vu, Eq. C-3
@ Left End	87.36 k	87.36 k	35.65 k	30.56 k
@ Right End	80.26 k	79.83 k	30.18 k	25.87 k

Deflection

Deflections...	Upward	Downward
DL + [Bm Wt]	0.0000 in at 30.0000 ft	-0.0939 in at 15.4800ft
DL + LL + [Bm Wt]	0.0000 in at 30.0000 ft	-0.2439 in at 15.4800ft
DL + LL + ST + [Bm Wt]	0.0000 in at 30.0000 ft	-0.0939 in at 15.4800ft
Reactions...	@ Left	@ Right
DL + [Bm Wt]	39.190 k	33.143 k
DL + LL + [Bm Wt]	65.017 k	64.617 k
DL + LL + ST + [Bm Wt]	39.190 k	33.143 k

Section Analysis

Evaluate Moment Capacity...	Center	Left End	Right End
X : Neutral Axis	3.080 in	4.965 in	2.825 in
a = beta * Xneutral	2.618 in	4.220 in	2.401 in
Compression in Concrete	106.814 k	172.186 k	97.971 k
Sum [Steel comp. forces]	0.000 k	0.000 k	0.000 k
Tension in Reinforcing	-601.451 k	-172.200 k	-98.012 k
Find Max As for Ductile Failure...			
X-Balanced	21.898 in	21.898 in	17.7551 in
Xmax = Xbal * 0.75	16.423 in	16.423 in	13.316 in
a-max = beta * Xbal	18.613 in	18.613 in	15.092 in
Compression in Concrete	2,079.166 k	569.566 k	461.810 k
Sum [Steel Comp Forces]	287.250 k	19.516 k	95.511 k
Total Compressive Force	2,366.416 k	589.082 k	557.321 k
AS Max = Tot Force / Fy	39.440 in ²	9.818 in ²	9.289 in ²
Actual Tension As	10.000 OK	2.870 OK	2.460 OK

Additional Deflection Calcs

Neutral Axis	7.270 in	Mcr	206.74 k-ft
Igross	167218.98 in ⁴	Ms:Max DL + LL	445.71 k-ft
Icracked	84,172.56 in ⁴	R1 = (Ms:DL+LL)/Mcr	0.464
Elastic Modulus	3,122.0 ksi	Ms:Max DL+LL+ST	248.46 k-ft
Fr = 7.5 * fc ^{0.5}	410.792 psi	R2 = (Ms:DL+LL+ST)/Mcr	0.832
Z:Cracking	83.108 k/in	I:eff... Ms(DL+LL)	92,460.739 in ⁴
		I:eff... Ms(DL+LL+ST)	132019.325 in ⁴
Eff. Flange Width	90.00 in		

ACI Factors (per ACI 318-02, applied internally to entered loads)

ACI C-1 & C-2 DL	1.400	ACI C-2 Group Factor	0.750	Add'l '1.4' Factor for Seismic	1.400
ACI C-1 & C-2 LL	1.700	ACI C-3 Dead Load Factor	0.900	Add'l '0.9' Factor for Seismic	0.900
ACI C-1 & C-2 ST	1.700	ACI C-3 Short Term Factor	1.300		
... seismic = ST *	1.100				

2.3 Rectangular Column

This program provides analysis of rectangular concrete columns loaded with axial loads and uniaxial bending moments. The program uses applied loads, reinforcing, material

strengths, and slenderness criteria to perform a complete numerical analysis of the column for ACI load combination equations 9-1, 9-2, and 9-3.

Axial loads can be applied at an eccentricity from the column centerline. Concentrated moments can be applied at the top or bottom. Lateral point and distributed loads can also be applied to the column, allowing the column to be analyzed with any degree of bending effects. All applied axial and bending loads can have dead, live, and short term components.

The evaluation of slenderness effects is provided by entering sidesway bracing status, effective length factors, and column heights. ACI section 10.11 is used to determine a moment magnification factor which will be applied to the resultant eccentricity. Up to five layers of reinforcing can be specified in the column, each with its own d distance. This provides the ability to analyze columns with different bar layouts (see below).

Column Data...

Column Width	21.000	in
Column Depth	24.000	in
Total Height	12.000	ft
Unbraced Length	24.000	ft
f'c	3,000.0	psi
Fy	60,000.0	psi
Seismic Zone	4	

Reinforcing...

Set #	# Bars	Bar Size	d' Depth
Set #1	5	6	2.400
Set #2	2	6	12.000
Set #3	5	6	21.600
Set #4	0	0	0.000
Set #5	0	0	0.000

Total Rebar Area: 5,280 in² 1,048 %

Slenderness...

Eff. Length Factor	1.000
Column Is Unbraced	<input type="checkbox"/>
Delta	1.000

Results

Column is OK

	ACIEq. C-1	ACIEq. C-2	ACIEq. C-3
Pu : Max Factored	432.14	432.14	432.14 k
Pn * Phi @ Design Ecc.	494.73	494.73	494.73 k
M-critical	303.67	303.67	303.67 k-ft
Combined Eccentricity	8.433	8.433	8.433 in
Magnification Factor	1.00	1.00	1.00
Design Eccentricity	8.433	8.433	8.433 in
Magnified Design Moment	303.67	303.67	303.67 k-ft
Po * .80	1,270.83	1,270.83	1,270.83 k
P : Balanced	578.72	578.72	578.72 k
Ecc : Balanced	10.889	10.889	10.889 in

Slenderness...

Actual k Lu / r	45.714	Beta	0.850
Elastic Modulus	3,122.0 ksi		

	ACIEq. C-1	ACIEq. C-2	ACIEq. C-3
Neutral Axis Distance	14.5450	14.5450	14.5450 in
Phi	0.7000	0.7000	0.7000
Max Limit k/r	34.0000	34.0000	34.0000
Beta = M:sustained/M:max	0.5232	0.5232	0.5232
Cm	0.6000	0.6000	0.6000
EI / 1000	19,833.87	19,833.87	19,833.87
Pc : phi ² E I / (k Lu) ²	2,360.06	2,360.06	2,360.06
alpha: MaxPu / (.75 Pc)	0.2441	0.2441	0.2441
Delta : Magnification Factor	1.0000	1.0000	1.0000
Ecc: Ecc Loads + Moments	8.4325	8.4325	8.4325 in
Design Ecc = Ecc * Delta	8.4325	8.4325	8.4325 in

Basic Usage

- Design Data Section allows you to enter material strengths, data effecting short-term load combinations, and slenderness data. Seismic Zone can be set to 0" to indicate wind, or 1 thru 4 to indicate seismic zones. For seismic zone 3 and 4, the additional load factoring provision of UBC section 2625 will be used. You can also specify whether the live load should be used in short-term load combinations.

- Slenderness factors describing the column bracing and effective length factors effect the actual length used to calculate column slenderness.
- In the Column Data section, enter the depth, width, and height of your column. The height will be used to calculate transverse column moments, due to applied distributed and point loads, and also for actual column length used for slenderness.
- You can enter up to five rebar sets for each column. These can be used to place reinforcing in different locations within the column. All sets allow you to specify bar #, count, and a d distance from the compression face (which, for reference of axial eccentricity and applied loads, is the right side of the column in the examples).
- Applied Loads include the axial and bending loads applied to the column. Because of the variety of loads available, sign convention is important.
- Axial Eccentricity: Positive eccentricity indicates the load is placed to the left of the column, applying a clockwise moment to the top of the column.
- Applied Moments: Positive moment applies a clockwise moment to the column.
- Applied Loads : Positive point and distributed loads force column's mid-span to deflect to the left, inducing tension on the left-hand fibers. (The deflection signs are created by applying the axial load at a positive eccentricity.)

Unique Features

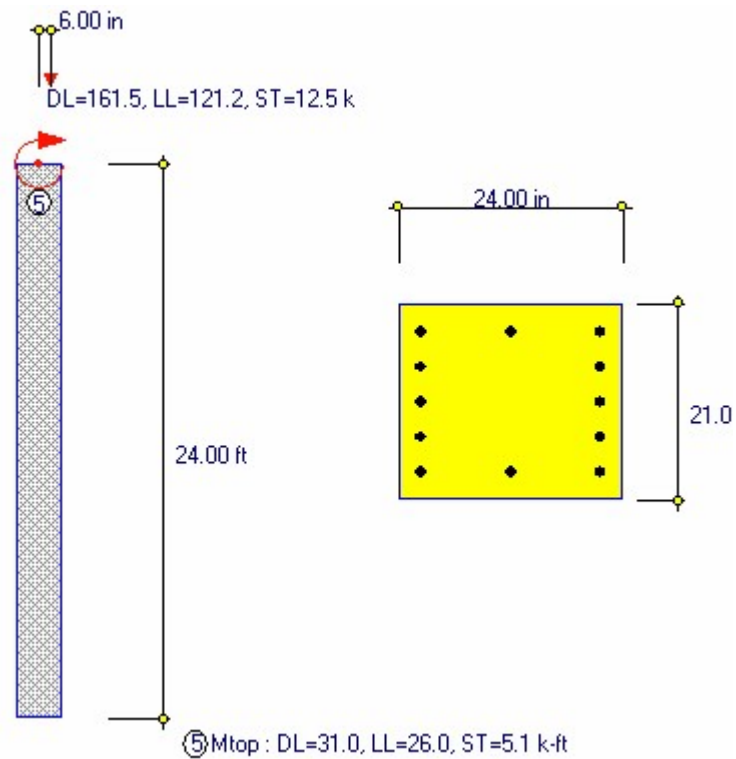
- Evaluates column slenderness and strength for all three ACI load factor combinations.
- Up to five layers of reinforcing are allowed at various depths in the column.
- Complete slenderness analysis is provided.
- Ability to combine beam type loads with eccentric axial loads.

Assumptions & Limitations

- Columns may be COMPRESSION ONLY....no tension.
- Determines an equivalent axial load and eccentricity for use in analyzing the concrete section. Applied moments, distributed loads, and point loads are combined with moments induced from axial load eccentricity, to form a moment diagram at 250th points along the column. The maximum moment is obtained from this analysis and used to calculate an equivalent eccentricity of the axial load. This eccentricity is then factored according to slenderness effects and used to calculate column load capacity.
- The program compares actual load and eccentricity with Ecc. Balanced to determine whether a compression or tension failure mode will control design strength.
- Column capacity assumes the code required lateral ties are provided.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow. Here is a sketch of the example:



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General | Loads | ACI Factors

Description Column with Applied End Moments

Column Data...

Column Width 21.000 in

Column Depth 24.000 in

Total Height 12.000 ft

Unbraced Length 24.000 ft

f_c 3,000.0 psi

F_y 60,000.0 psi

Seismic Zone 4

Include LL w/ ST Loads

Reinforcing...

	# Bars	Bar Size	'd' Depth
Set #1	5	6	2.400 in
Set #2	2	6	12.000 in
Set #3	5	6	21.600 in
Set #4	0	0	0.000 in
Set #5	0	0	0.000 in
Total Rebar Area			5.280 in ² 1.048 %

Slenderness...

Eff. Length Factor 1.000

Column is Unbraced

Delta:S 1.000

Column Width

Enter the column width here.

Column Depth

Enter the column depth. Moments applied to the column will create tension and compression on the outer edges of the "depth" dimension.

Total Height

This is the total height of the column and is only needed if you are entering applied lateral loads to the column. If you are this length is needed to perform the beam analysis to determine the moments along the column's length.

Unbraced Length

Enter the unbraced length of the column that should be use in the calculation of column slenderness.

f_c

Specified 28 day compressive strength of concrete to be used.

F_y

Yield strength of reinforcing steel to be used.

Seismic Zone

This item specifies whether the short term loads are due to wind or seismic forces. Entering a 0" indicates that short-term loads are due to wind. Entering 1" to 4" specifies that the short-term loads come from UBC seismic zone loads. Additionally, when zone 3 and 4 are used, the special load factoring for that zone required by the UBC are used.

Include Live Load w/ Short Term Loads

This entry controls whether or not live loads are used when ACI load combination C-2 calculations are executed. When short-term loads are due to wind forces, live loads are typically used, whereas seismic forces usually ignore live load effects (except high storage loads).

Reinforcing Specification

Enter your reinforcing selection in this area. You have the option of entering up to five layers of rebar, each with its own size, quantity, and depth. The concrete section analysis procedures will use the total area and d distance to each layer to determine internal strains and forces.

Bar Size

Enter the bar size in each layer. The size # and count will determine the reinforcing area in each layer.

Bar Count

Enter the number of bars in each layer.

d - Depth to Rebar

Enter the distance from extreme compression/tension fiber to the centerline of reinforcing layer.

Effective Length Factor

This factor is applied to the unbraced length to determine L_u . The common reference for k factors can be found in the AISC handbook, Figure C1.8.1

Unbraced Column ?

Leave this box unchecked if the column is braced against sidesway. Check this box , if it's free to deflect laterally when loaded.

When the column is unbraced, the effective length used to calculated slenderness will be adjusted. For unbraced columns, a factor must also be entered to magnify eccentricity further. Please see the explanation for $M2S * \Delta S$.

For braced columns, slenderness is neglected if:
 $k L_u/r < (34 - 12(M1/M2))$ Where $M1 > M2$

For unbraced columns, slenderness is neglected if:
 $k L_u/r < 22$.

Delta:s

For unbraced columns, ACI equation 10-6 requires that a magnification factor to account for the entire frame systems potential to drift be specified. Enter that factor here, and it will be added to the magnification factor calculated in the program, before application to the design eccentricity to calculate final eccentricity.

Load Entry Tab

This section allows you to enter loads on the column to be included in the analysis. Using the applied moments, point loads, distributed loads, and moment induced by axial load eccentricity, a moment diagram for the column is internally constructed. The maximum moment in the column is then used to determine an equivalent eccentricity of the applied axial load. This

eccentricity is used for all further analysis procedures to determine neutral axis location, internal strains, and compressive capacity. All applied loads may have dead, live, and short term components. Load factoring of short-term components is governed by the Seismic Zone entry.

General		Loads	ACI Factors
Axial Loads...			
	<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
	161.500 k	121.200 k	12.500 k
	Eccentricity =		6.000 in
Applied Moments...			
	<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
@ Top	31.000 k-ft	26.000 k-ft	5.100 k-ft
@ Bottom			
Lateral Uniform Loads...			
	<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
# 1			
	Start -> End ::		0.000 ft >> 0.000 ft
# 2			
	Start -> End ::		0.000 ft >> 0.000 ft
Lateral Point Loads...			
	<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>
# 1			
	Location =		0.000 ft
# 2			
	Location =		0.000 ft

Axial

Enter the maximum axial dead, live, and short-term loads and moments the column will be subjected to. Do not apply load factors to these loads.

Applied Loads

Eccentricity For the previously entered axial loads, you may specify an eccentricity to the column Depth centerline. This induced top moment will be combined with the other moments to determine final moment and load eccentricity. A positive eccentricity applies a clockwise moment to the top of the column.

Moments

You may enter a concentrated moment applied to the top or bottom of the column. Positive moments

apply a clockwise torque to the column.

Uniform

Up to two full or partial length uniform loads can be applied to create bending moments between supports. Positive uniform loads act to deflect the column to the left (side of negative axial eccentricity).

Point

Up to two concentrated loads can be applied to create bending moments between supports. Positive uniform loads act to deflect the column to the left (side of negative axial eccentricity).

ACI Factors Tab

This tab specifies the load factors to be used by the program when calculation the factored dead, live, and short term loads to be used in the internal load combinations for determining P_u and M_u for the column.

General		Loads		ACI Factors	
Load Factors... (Nomenclature per ACI 318-02 Appx C)					
ACI C-1 & C-2 Dead Load					
ACI C-1 & C-2 Live Load					
ACI C-1 & C-2 Short Term					
....seismic = ST * :					C-1, C-2, and C-3
ACI C-2 Group Factor					
ACI C-3 Dead Load Factor					
ACI C-3 Short Term Factor					
Additional factors for Seismic Zone 3 & 4					
"1.4" Factor					
"0.9" Factor					

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results Tab

The program performs a detailed analysis of the column for ACI load combinations C-1, C-2, and C-3. Using the applied loads, an equivalent eccentricity is calculated and then factored by the Moment Magnification Factor which was evaluated considering slenderness effects. This eccentricity is used to calculate internal strains and forces. These forces are resolved into

allowable axial capacities. A satisfactory design results when $P_u \leq P_n * \Phi$ for all three ACI load combinations.

Results	Sketch	Diagrams	Printing
Column is OK			
	<u>ACI Eq. C-1</u>	<u>ACI Eq. C-2</u>	<u>ACI Eq. C-3</u>
Pu : Max Factored	432.14	432.14	432.14 k
Pn * Phi @ Design Ecc.	494.73	494.73	494.73 k
M-critical	303.67	303.67	303.67 k-ft
Combined Eccentricity	8.433	8.433	8.433 in
Magnification Factor	1.00	1.00	1.00
Design Eccentricity	8.433	8.433	8.433 in
Magnified Design Moment	303.67	303.67	303.67 k-ft
Po * .80	1,270.83	1,270.83	1,270.83 k
P : Balanced	578.72	578.72	578.72 k
Ecc : Balanced	10.889	10.889	10.889 in
Slenderness...			
Actual k Lu / r	45.714	Beta	0.850
Elastic Modulus	3,122.0 ksi		
	<u>ACI Eq. C-1</u>	<u>ACI Eq. C-2</u>	<u>ACI Eq. C-3</u>
Neutral Axis Distance	14.5450	14.5450	14.5450 in
Phi	0.7000	0.7000	0.7000
Max Limit k/r	34.0000	34.0000	34.0000
Beta = M:sustained/M:max	0.5232	0.5232	0.5232
Cm	0.6000	0.6000	0.6000
EI / 1000	19,833.87	19,833.87	19,833.87
Pc : pi^2 EI / (k Lu)^2	2,360.06	2,360.06	2,360.06
alpha: MaxPu / (.75 Pc)	0.2441	0.2441	0.2441
Delta : Magnification Factor	1.0000	1.0000	1.0000
Ecc: Ecc Loads + Moments	8.4325	8.4325	8.4325 in
Design Ecc = Ecc * Delta	8.4325	8.4325	8.4325 in

Pu : Max Factored Axial Load

Maximum factored axial load for each ACI equation.

Pn * Phi @ Design Eccentricity

Maximum compressive load capacity of the column considering size, reinforcing, and slenderness. Phi equals 0.70 since this program deals with rectangular tied columns.

Final Eccentricity

This eccentricity is obtained by calculating an equivalent eccentricity at which the axial loads would have to be applied to create the same maximum moment as created by all applied bending loads. Minimum eccentricity is $0.6 + 0.03 * \text{Diameter}$.

Magnification Factor

This factor is determined by slenderness effects (see next section).

Design Eccentricity

This is the eccentricity used for determining column capacity, and is equal to Final Eccentricity * Magnification Factor.

Po * .80

This is the column capacity if no slenderness or bending were effecting the column.

P : Bal & Ecc. Bal.

Balanced load and eccentricity are calculated to verify whether the column is working in a Tension Failure or Compression Failure mode. This load, when applied at the Balanced Eccentricity , produces simultaneous ultimate strains in concrete and steel. This value is given only for reference.

Slenderness Effects**Actual $k*Lu/r$**

This value will be used for the column slenderness calculations. k and Lu have already been entered. r, the radius of gyration, is equal to $0.288*Depth$.

Beta

This is the typical concrete factor: $Beta=0.85 - 0.05(f'c-4000)/1000$

Elastic Modulus

This is calculated as: $57,000 * (f'c)^{1/2}$ Because the neutral axis distance varies according to the Design Eccentricity, the slenderness analysis is completed for all ACI load combinations.

Neutral Axis Dist.

The neutral axis distance represents the point at which compression and tension forces are balanced for the section and design eccentricity.

Phi

The Phi factor is calculated by balancing the effects of axial and bending loads in accordance with ACI section 9.3.2.2.

Max. K Lu/r to Neglect

The maximum allowable slenderness ratio is calculated in accordance with ACI 10.11.4, considering unbraced length, effective length factor, radius of gyration, and bracing status.

Beta

Ratio of factored dead load moment to factored total load moment.

Cm

Cm is determined in accordance with ACI 10.11.5.3.

EI

This represents the minimum value of ACI equation 10-10 and 10-11. (ACI states that either value can be used, so both are calculated and the minimum taken to be conservative).

Pc

Critical buckling load, calculated using equation 10-9.

Alpha

This value will be used to calculate the actual magnification factor, and is the ratio of $P_u/(Phi * P_c)$ from ACI equation 10-7.

Delta

Actual moment magnification factor calculated using ACI equation 10-7.

Eccentricity

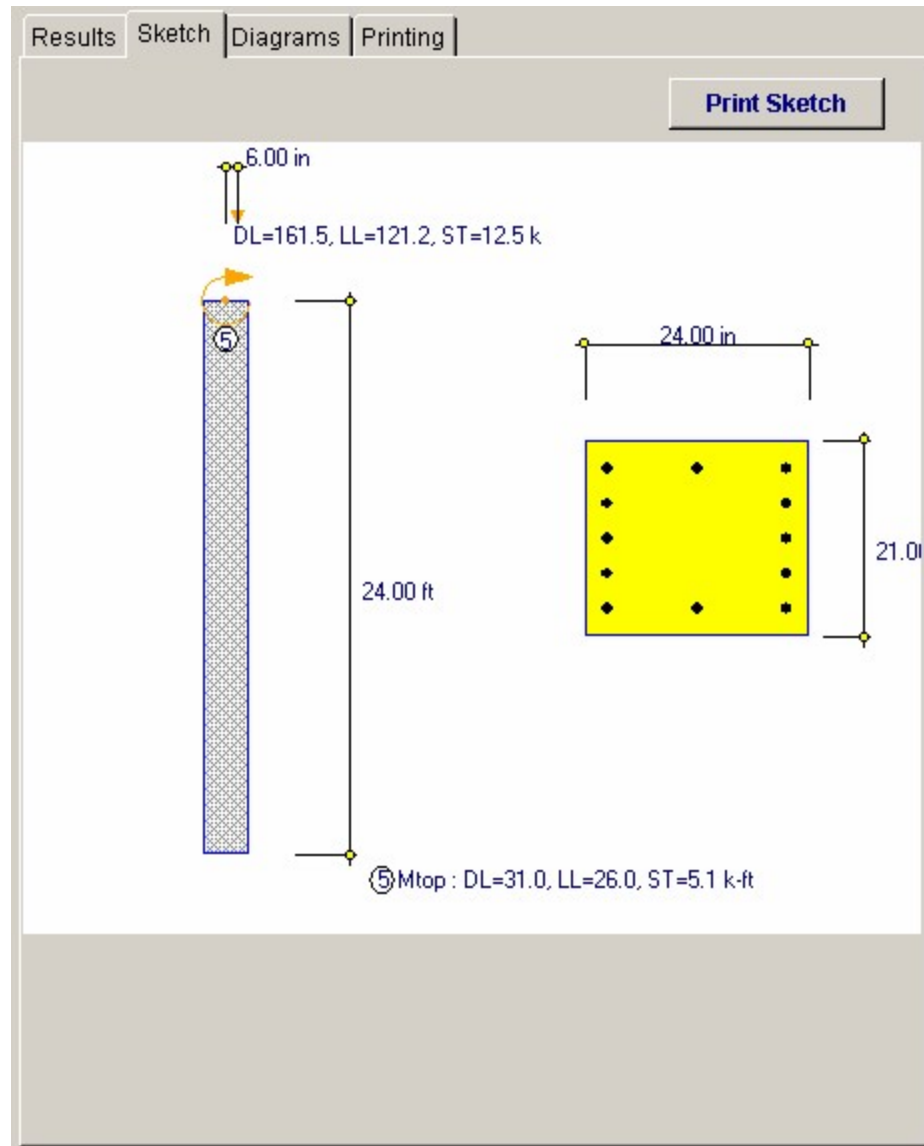
Please see Final Eccentricity in the section titled Summary.

Design Ecc.

Please see Design Eccentricity in the section titled Summary.

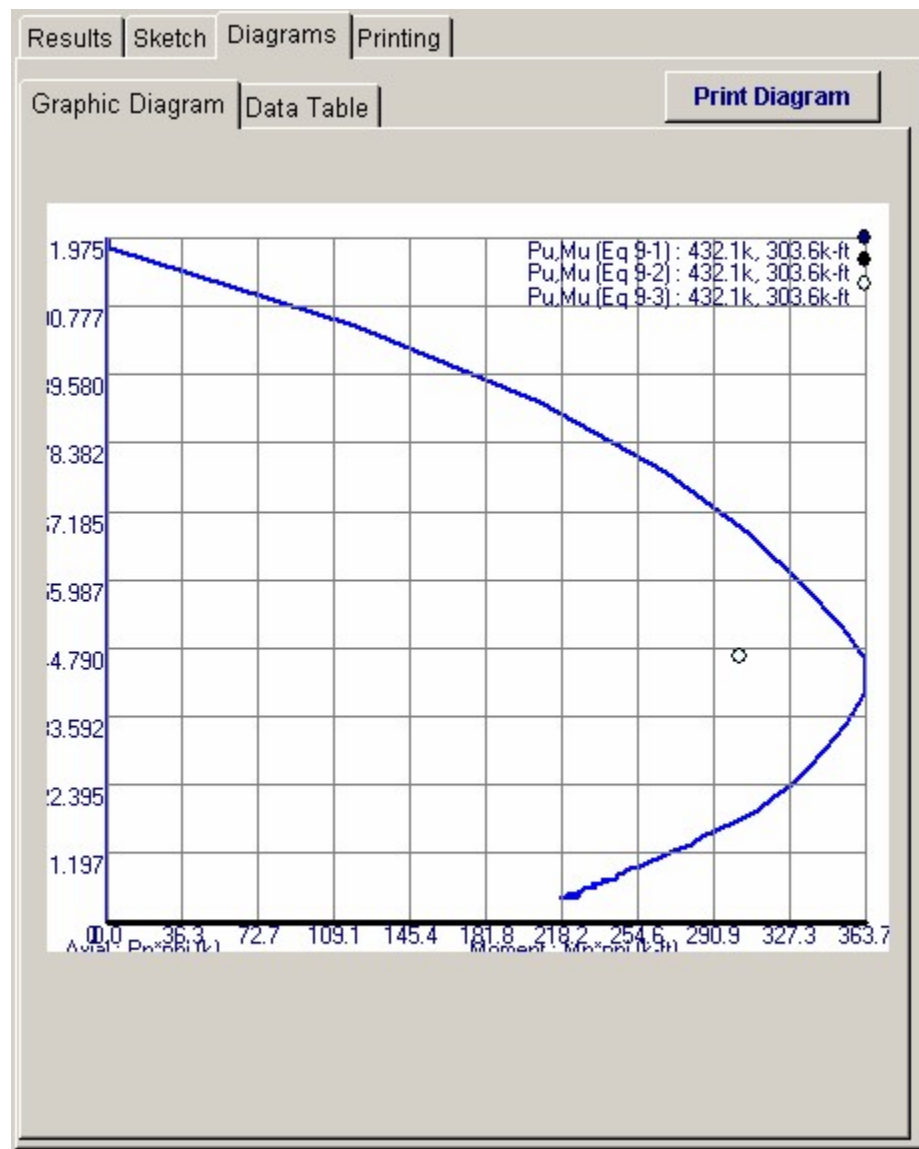
Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Diagrams Tab

This displays a moment, shear, and deflection diagram for the beam with the applied loads and end conditions. Note the two tabs...."Graphic Diagram" and "Data Table". The Data Table tab provides the entire internal analysis at the 1/500th points within the beam.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Diagrams | Printing

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Loads	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Slenderness	<input checked="" type="checkbox"/>
ACI Factors	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections.

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 10:46PM, 26 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 980000
 User: KW-0000001, Ver 6.8.0, 10-Sep-2003
 (c)1993-2003 ENERCALC Engineering Software

Rectangular Concrete Column

Page 1

c:\ec55\examples\concrete\Colcs

Description Column with Applied End Moments

General Information

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Width	21.000 in	f'c	3,000.0 psi	Total Height	12.000 ft
Depth	24.000 in	Fy	60,000.0 psi	Unbraced Length	24.000 ft
Rebar:		Seismic Zone	4	Eff. Length Factor	1.000
5- # 6 d =	2.400 in	LL & ST Loads Act Separately		Column is BRACED	
2- # 6 d =	12.000 in				
5- # 6 d =	21.600 in				

Loads

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design.
 Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

	Dead Load	Live Load	Short Term	Eccentricity
Axial Loads	161.500 k	121.200 k	12.500 k	6.000 in
Applied Moments...				
@ Top	31.000 k-ft	26.000 k-ft	5.100 k-ft	
@ Bottom	k-ft	k-ft	k-ft	

Summary

Column is OK

21.00 x 24.00in Column, Rebar: 5-#6 @ 2.40in, 2-#6 @ 12.00in, 5-#6 @ 21.60in

	ACI C-1	ACI C-2	ACI C-3
Applied : Pu : Max Factored	432.14 k	432.14 k	432.14 k
Allowable : Pn * Phi @ Design Ecc.	494.73 k	494.73 k	494.73 k
M-critical	303.67 k-ft	303.67 k-ft	303.67 k-ft
Combined Eccentricity	8.433 in	8.433 in	8.433 in
Magnification Factor	1.00	1.00	1.00
Design Eccentricity	8.433 in	8.433 in	8.433 in
Magnified Design Moment	303.67 k-ft	303.67 k-ft	303.67 k-ft
Po * .80	1,270.83 k	1,270.83 k	1,270.83 k
P : Balanced	578.72 k	578.72 k	578.72 k
Ecc : Balanced	10.889 in	10.889 in	10.889 in

Slenderness

per ACI 318-95 Section 10.12 & 10.13

Actual k Lu / r	Elastic Modulus	Beta
45.714	3,122.0 ksi	0.850
	ACI Eq. C-1	ACI Eq. C-2
Neutral Axis Distance	14.5450 in	14.5450 in
Phi	0.7000	0.7000
Max Limit k/r	34.0000	34.0000
Beta = M:sustained/M:max	0.5232	0.5232
Cm	0.6000	0.6000
EI / 1000	19,833.87	19,833.87
Pc : pi^2 EI / (k Lu)^2	2,360.06	2,360.06
alpha: MaxPu / (.75 Pc)	0.2441	0.2441
Delta	1.0000	1.0000
Ecc: Ecc Loads + Moments	8.433	8.433
Design Ecc = Ecc * Delta	8.433	8.433
	ACI Eq. C-3	ACI Eq. C-3
	14.5450 in	14.5450 in
	0.7000	0.7000
	34.0000	34.0000
	0.5232	0.5232
	0.6000	0.6000
	19,833.87	19,833.87
	2,360.06	2,360.06
	0.2441	0.2441
	1.0000	1.0000
	8.433 in	8.433 in
	8.433	8.433

ACI Factors (per ACI 318-02, applied internally to entered loads)

ACI C-1 & C-2 DL	ACI C-2 Group Factor	Add'l "1.4" Factor for Seismic
1.400	0.750	1.400
ACI C-1 & C-2 LL	ACI C-3 Dead Load Factor	Add'l "0.9" Factor for Seismic
1.700	0.900	0.900
ACI C-1 & C-2 ST	ACI C-3 Short Term Factor	
1.700	1.300	
... seismic = ST * :	1.100	

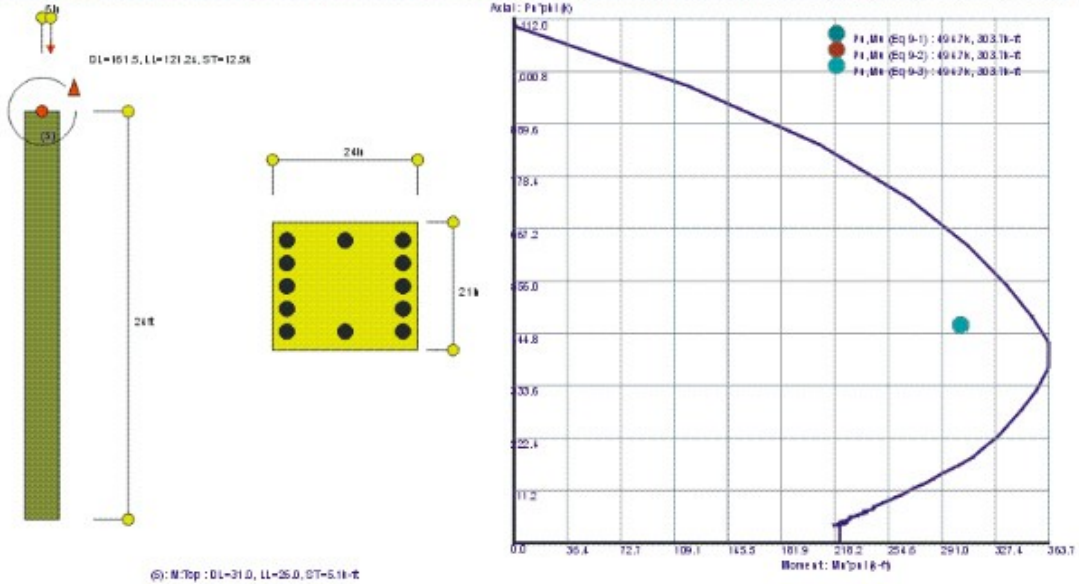
ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title : ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 10:48PM, 26 OCT 03
 Description : Collection of example problems
 Scope : All programs in the Structural Engineering Library

Rev: 560000 User: K/W-0900001, Ver 5.8.0, 10-Sep-2003 (c)1983-2003 ENERCALC Engineering Software	Rectangular Concrete Column	Page 2 <small>c:\enrcb\examples\enrc\Concrete Calc</small>
--	------------------------------------	---

Description Column with Applied End Moments

Sketch & Diagram



2.4 Circular Column

This program provides analysis of circular concrete columns loaded with axial loads and bending moments about one axis. The program uses applied loads, reinforcing, material strengths, and slenderness criteria to perform a complete numerical analysis of the column for ACI load combination equations 9-1, 9-2, and 9-3.

Axial loads can be applied at an eccentricity to the column centerline. Concentrated moments can be applied at the top or bottom. Point and distributed loads can also be applied laterally to the column, allowing the column to be analyzed with any degree of

bending effect. All applied axial and bending loads can have dead, live, and short term components.

The evaluation of slenderness effects is provided by entering sidesway bracing status, effective length factors, and column heights. ACI section 10.11 is used to determine a moment magnification factor which will be applied to the resultant eccentricity. You can specify reinforcing to be placed at a clear distance from the column face in a circular pattern, and specify whether spirals will be used to increase column capacity.

Column is OK			
	ACI Eq. C-1	ACI Eq. C-2	ACI Eq. C-3
Pu : Max Factored	432.14	285.60	204.85 k
Pn * Phi @ Dsgn Ecc.	797.85	797.85	797.85 k
M-critical	218.07	142.80	102.42 k-ft
Combined Eccentricity	6.0000	6.0000	6.0000 in
Magnification Factor	1.00	1.00	1.00
Design Eccentricity	6.0000	6.0000	6.0000 in
Magnified Moment	218.07	142.80	102.42 k-ft
Po * 80	1,703.95	1,703.95	1,703.95 k
P : Balanced	677.52	677.52	677.52 k
Ecc : Balanced	10.8365	10.8365	10.8365 in
Slenderness....			
Actual k Lu / r	37.333	Beta	0.850
Elastic Modulus	3,122,019 ksi		
Neutral Axis Distance			
	ACI Eq. C-1	ACI Eq. C-2	ACI Eq. C-3
Neutral Axis Distance	18.4735	18.4735	18.4735 in
Phi	0.7500	0.7500	0.7500
Max Limit k/r	37.3289	37.1369	37.0588
Beta = Msustained/Mmax	0.5232	0.7917	0.7095
Cm	0.4890	0.4954	0.4960
EI / 1000	21,813.24	18,374.79	19,257.48
Po : pi² E I / (k Lu)²	3,369.07	2,855.76	2,992.94
alpha: MaxPu / (.75 Pc)	0.1715	0.1333	0.0913
Delta : Magnification Factor	1.0000	1.0000	1.0000
Ecc: Ecc Loads + Moments	6.0000	6.0000	6.0000 in
Design Ecc = Ecc * Delta	6.0000	6.0000	6.0000 in

Basic Usage

- The Design Data Section allows you to enter material strengths, data affecting short-term load combinations, and slenderness data. Seismic Zone can be set to 0" to indicate wind, or 1" thru 4" to indicate seismic zones. For seismic zone 3 and 4, the additional load factoring provision of UBC section 2625 will be used. You can also specify whether the live load should be used in short-term load combinations.
- Slenderness factors describing the column bracing and effective length factors effect the actual length used to calculate column slenderness.
- In the Column Data section, enter the diameter and height of your column. The height will be used to calculate transverse column moments due to applied distributed and point loads, and also for actual length used for column slenderness. Also, enter the reinforcing and clear cover from the rebar centerline to face of

column.

- Applied Loads include the axial and bending loads applied to the column. Because of the variety of loads available, sign convention is important.
- Positive eccentricity indicates the load is placed to the left of the column, applying a counter-clockwise moment to the top of the column (following the right-hand rule).
- Applied Moments: Positive moment applies a clockwise moment to the column.
- Applied Loads: Positive point and distributed loads force column's mid-height to deflect to the left, inducing tension on the left-hand fibers.

Unique Features

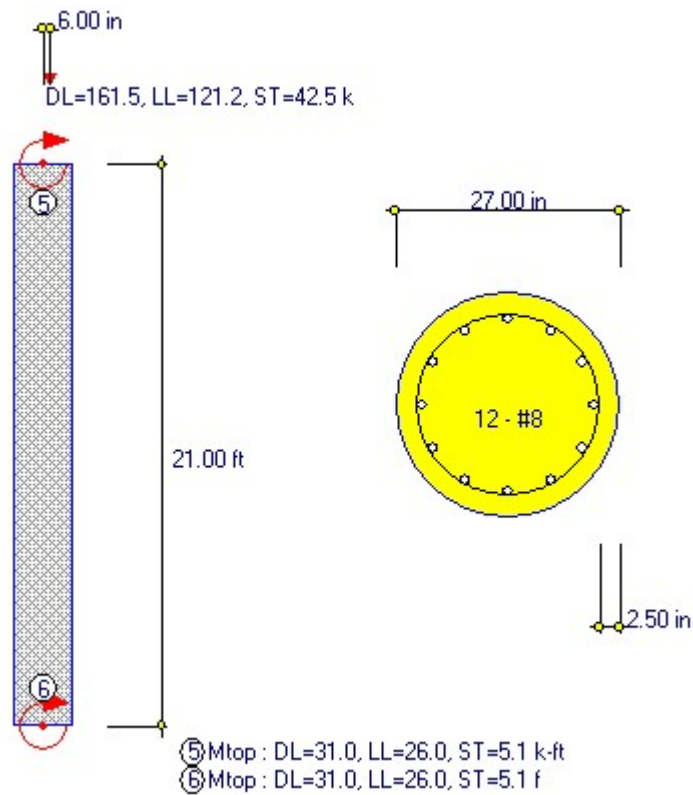
- Program evaluates column slenderness and strength for all three ACI load factor combinations.
- Easily specify reinforcing size and bar count at a cover distance from the column face. The program will automatically distribute the bars evenly around the circumference.
- Complete slenderness analysis is provided.
- Ability to combine beam type loads with eccentric axial loads.

Assumptions & Limitations

- Square rebar cages are not allowed.
- Program determines an equivalent axial load and eccentricity for use in analyzing the concrete section. Applied moments, distributed loads, and point loads are combined with moments induced from axial load eccentricity to form a bending analysis at 250th points along the column. The maximum moment is obtained from this analysis and used to calculate an equivalent eccentricity of the axial load. This eccentricity is then factored according to slenderness effects and used to calculate column load capacity.
- The program compares actual load and eccentricity with Ecc. Balanced to determine whether a compression or tension failure mode will control design strength.
- Column capacity assumes the code required lateral ties are provided.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General	Loads	Spiral Ties	ACI Factors
Description			
Column with Applied End Moments			
Column Data....			
Diameter	27.000	in	
Total Height	0.000	ft	
Unbraced Length	21.000	ft	
f_c	3,000.0	psi	
F_y	60,000.0	psi	
Seismic Zone	4		
Include LL w/ ST Loads	<input type="checkbox"/>		
Reinforcing....			
Number of Bars	12		
Bar Size	8		
Total Rebar Area	9.480 in ²	:	1.656 %
Bar Cover	2.500	in	
Stirrups / Slenderness...			
Eff. Length Factor	1.000		
Column is Unbraced	<input type="checkbox"/>		
Delta:S	1.000		

Column Diameter

The outside diameter of the concrete column.

Total Height

This is the total height of the column and is only needed if you are entering applied lateral loads to the column. If you are this length is needed to perform the beam analysis to determine the moments along the column's length.

Unbraced Length

Enter the unbraced length of the column that should be use in the calculation of column slenderness.

 f_c

Specified 28 day compressive strength of concrete to be used.

 F_y

Yield strength of reinforcing steel to be used.

Seismic Zone

This item specifies whether the short term loads are due to wind or seismic forces. Entering a 0" indicates that short-term loads are due to wind. Entering 1" to 4" specifies that the short-term loads come from UBC seismic zone loads. Additionally, when zone 3 and 4 are used, the special load factoring for that zone required by the UBC are used.

Include Live Load w/ Short Term Loads

This entry controls whether or not live loads are used when ACI load combination C-2 calculations are executed. When short-term loads are due to wind forces, live loads are typically used, whereas seismic forces usually ignore live load effects (except high storage loads).

Number of Bars

Enter the number of bars vertically in the column that are enclosed in ties to be considered as reinforcement.

Bar Size #

Enter the bar size in each layer. The size # and count will determine the reinforcing area in each layer.

Total Rebar Area

Area of rebar (number of bars * bar area).

Bar Cover

This is the distance from the edge of the bar to the outside edge of the column.

Effective Length Factor

This factor is applied to the unbraced length to determine L_u . The common reference for k factors can be found in the AISC handbook, Figure C1.8.1

Unbraced Column ?

Leave this box unchecked if the column is braced against sidesway. Check this box , if it's free to deflect laterally when loaded.

When the column is unbraced, the effective length used to calculate slenderness will be adjusted. For unbraced columns, a factor must also be entered to magnify eccentricity further. Please see the explanation for $M_2S * \Delta S$.

For braced columns, slenderness is neglected if:
 $k L_u/r < (34 - 12(M_1/M_2))$ Where $M_1 > M_2$

For unbraced columns, slenderness is neglected if:
 $k L_u/r < 22$.

Delta:s

For unbraced columns, ACI equation 10-6 requires that a magnification factor to account for the entire frame systems potential to drift be specified. Enter that factor here, and it will be added to the magnification factor calculated in the program, before application to the design eccentricity to calculate final eccentricity.

Loads Tab

This section allows you to enter loads on the column to be included in the analysis. Using the applied moments, point loads, distributed loads, and moment induced by axial load eccentricity, a moment diagram for the column is internally constructed. The maximum moment in the column is then used to determine an equivalent eccentricity of the applied axial load. This eccentricity is used for all further analysis procedures to determine neutral axis location, internal strains, and compressive capacity. All applied loads may have dead, live, and short

term components. Load factoring of short-term components is governed by the Seismic Zone entry.

General	Loads	Spiral Ties	ACI Factors
Axial Loads....			
<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>	
161.500	121.200	42.500	k
Eccentricity =		6.000	in
Applied Moments...			
<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>	
@ Top	31.000	26.000	5.100 k-ft
@ Bottom	31.000	26.000	5.100 k-ft
Lateral Uniform Loads...			
<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>	
#1			k/ft
Start -> End ::	0.00	ft ->	0.00 ft
#2			k/ft
Start -> End ::	0.00	ft ->	0.00 ft
Lateral Point Loads...			
<u>Dead Load</u>	<u>Live Load</u>	<u>Short Term</u>	
#1			k
Location =		0.00	ft
#2			k
Location =		0.00	ft

Axial

Enter the maximum axial dead, live, and short-term loads and moments the column will be subjected to. Do not apply load factors to these loads.

Applied Loads

Eccentricity For the previously entered axial loads, you may specify an eccentricity to the column Depth centerline. This induced top moment will be combined with the other moments to determine final moment and load eccentricity. A positive eccentricity applies a clockwise moment to the top of the column.

Moments

You may enter a concentrated moment applied to the top or bottom of the column. Positive moments apply a clockwise torque to the column.

Uniform

Up to two full or partial length uniform loads can be applied to create bending moments between supports. Positive uniform loads act to deflect the column to the left (side of negative axial eccentricity).

Point

Up to two concentrated loads can be applied to create bending moments between supports. Positive uniform loads act to deflect the column to the left (side of negative axial eccentricity).

Spiral Ties Tab

This tab is used to specify the spiral ties that are used in the column. If the checkbox for "Spiral Ties used" is not checked then the program will assume non-continuous simply hoop ties.

General	Loads	Spiral Ties	ACI Factors
Spiral Spacing Calculations.....			
Spiral Ties Used			<input checked="" type="checkbox"/>
Spiral Bar Size	#	<input type="text" value="3"/>	<input type="button" value="v"/>
Ag : Gross Section Area		572.55 in ²	
Ac : Core Area		380.13 in ²	
Min. Spiral Reinforcement Ratio		0.01139	
<i>ACI 1910.9.3 : Ratio = 0.45(Ag/Ac - 1) * f_c/f_y</i>			
Max. Spiral Spacing		1.756 in	

ACI Factors Tab

This tab specifies the load factors to be used by the program when calculation the factored dead, live, and short term loads to be used in the internal load combinations for determining Pu and Mu for the column.

General	Loads	Spiral Ties	ACI Factors
Load Factors		Nomenclature per ACI 318-02 Appx C	
ACI C-1 & C-2 for Dead Load		<input type="text" value="1.400"/>	
ACI C-1 & C-2 for Live Load		<input type="text" value="1.700"/>	
ACI C-1 & C-2 for Short Term		<input type="text" value="1.700"/>	
....seismic = ST * :		<input type="text" value="1.100"/>	(C-11, C-2, and C-3)
ACI C-2 Group Factor		<input type="text" value="0.750"/>	
ACI C-3 Dead Load Factor		<input type="text" value="0.900"/>	
ACI C-3 Short Term Factor		<input type="text" value="1.300"/>	
Additional factors for Seismic Zone 3 & 4			
"1.4" Factor		<input type="text" value="1.400"/>	
"0.9" Factor		<input type="text" value="0.900"/>	

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results Tab

The program performs a detailed analysis of the column for ACI load combinations C-1, C-2, and C-3. Using the applied loads, an equivalent eccentricity is calculated and then factored by the Moment Magnification Factor which was evaluated considering slenderness effects. This eccentricity is used to calculate internal strains and forces. These forces are resolved into allowable axial capacities. A satisfactory design results when $P_u \leq P_n * \Phi$ for all three ACI load combinations.

Results	Sketch	Diagrams	Printing
Column is OK			
	<u>ACI Eq. C-1</u>	<u>ACI Eq. C-2</u>	<u>ACI Eq. C-3</u>
Pu : Max Factored	432.14	285.60	204.85 k
Pn * Phi @ Dsgn Ecc.	797.85	797.85	797.85 k
M-critical	216.07	142.80	102.42 k-ft
Combined Eccentricity	6.0000	6.0000	6.0000 in
Magnification Factor	1.00	1.00	1.00
Design Eccentricity	6.0000	6.0000	6.0000 in
Magnified Moment	216.07	142.80	102.42 k-ft
Po * .80	1,703.95	1,703.95	1,703.95 k
P : Balanced	677.52	677.52	677.52 k
Ecc : Balanced	10.8365	10.8365	10.8365 in
Slenderness.....			
Actual k Lu / r	37.333	Beta	0.850
Elastic Modulus	3,122.019 ksi		
	<u>ACI Eq. C-1</u>	<u>ACI Eq. C-2</u>	<u>ACI Eq. C-3</u>
Neutral Axis Distance	18.4735	18.4735	18.4735 in
Phi	0.7500	0.7500	0.7500
Max Limit kl/r	37.3289	37.1369	37.0588
Beta = M:sustained/M:max	0.5232	0.7917	0.7095
Cm	0.4890	0.4954	0.4980
EI / 1000	21,613.24	18,374.79	19,257.48
Pc : pi ² EI / (k Lu) ²	3,359.07	2,855.76	2,992.94
alpha: MaxPu / (.75 Pc)	0.1715	0.1333	0.0913
Delta : Magnification Factor	1.0000	1.0000	1.0000
Ecc: Ecc Loads + Moments	6.0000	6.0000	6.0000 in
Design Ecc = Ecc * Delta	6.0000	6.0000	6.0000 in

Pu : Max Factored Axial Load

Maximum factored axial load for each ACI equation.

Pn * Phi @ Design Eccentricity

Maximum compressive load capacity of the column considering size, reinforcing, and slenderness. Phi equals 0.70 since this program deals with rectangular tied columns.

Final Eccentricity

This eccentricity is obtained by calculating an equivalent eccentricity at which the axial loads would have to be applied to create the same maximum moment as created by all applied bending loads. Minimum eccentricity is $0.6 + 0.03 \times \text{Diameter}$.

Magnification Factor

This factor is determined by slenderness effects (see next section).

Design Eccentricity

This is the eccentricity used for determining column capacity, and is equal to Final Eccentricity * Magnification Factor.

Po * .80

This is the column capacity if no slenderness or bending were effecting the column.

P : Bal & Ecc. Bal.

Balanced load and eccentricity are calculated to verify whether the column is working in a Tension Failure or Compression Failure mode. This load, when applied at the Balanced Eccentricity , produces simultaneous ultimate strains in concrete and steel. This value is given only for reference.

Slenderness Effects**Actual $k*Lu/r$**

This value will be used for the column slenderness calculations. k and Lu have already been entered. r, the radius of gyration, is equal to $0.288*Depth$.

Beta

This is the typical concrete factor: $Beta=0.85 - 0.05(f'c-4000)/1000$

Elastic Modulus

This is calculated as: $57,000 * (f'c)^{1/2}$ Because the neutral axis distance varies according to the Design Eccentricity, the slenderness analysis is completed for all ACI load combinations.

Neutral Axis Dist.

The neutral axis distance represents the point at which compression and tension forces are balanced for the section and design eccentricity.

Phi

The Phi factor is calculated by balancing the effects of axial and bending loads in accordance with ACI section 9.3.2.2.

Max. K Lu/r to Neglect

The maximum allowable slenderness ratio is calculated in accordance with ACI 10.11.4, considering unbraced length, effective length factor, radius of gyration, and bracing status.

Beta

Ratio of factored dead load moment to factored total load moment.

Cm

CM is determined in accordance with ACI 10.11.5.3.

EI

This represents the minimum value of ACI equation 10-10 and 10-11. (ACI states that either value can be used, so both are calculated and the minimum taken to be conservative).

Pc

Critical buckling load, calculated using equation 10-9.

Alpha

This value will be used to calculate the actual magnification factor, and is the ratio of $P_u/(Phi * P_c)$ from ACI equation 10-7.

Delta

Actual moment magnification factor calculated using ACI equation 10-7.

Eccentricity

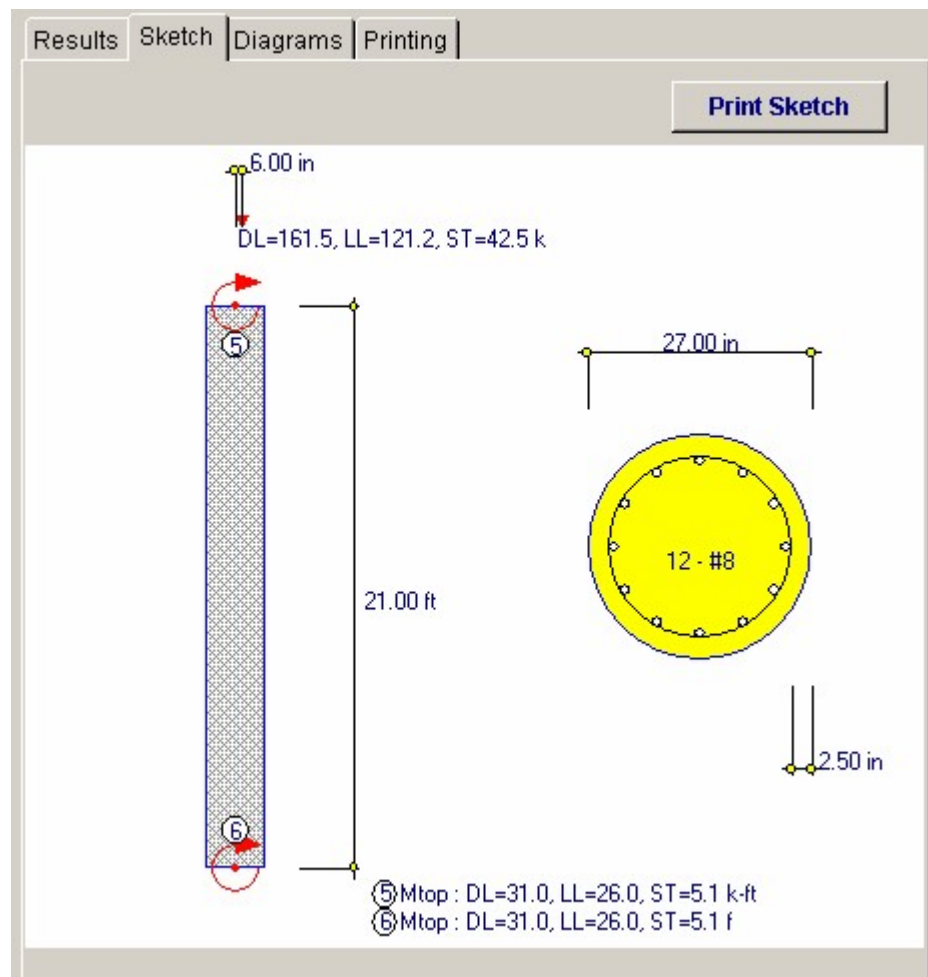
Please see Final Eccentricity in the section titled Summary.

Design Ecc.

Please see Design Eccentricity in the section titled Summary.

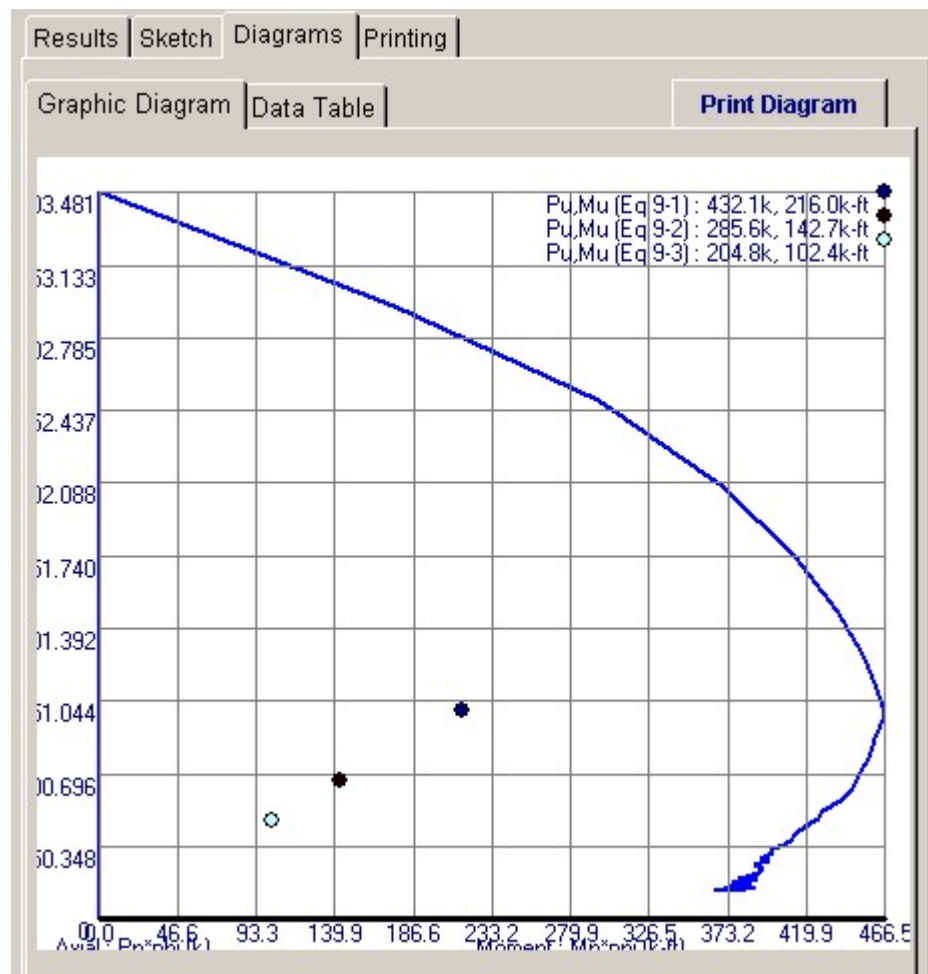
Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Diagrams Tab

This displays a moment, shear, and deflection diagram for the beam with the applied loads and end conditions. Note the two tabs...."Graphic Diagram" and "Data Table". The Data Table tab provides the entire internal analysis at the 1/500th points within the beam.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Diagrams | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Loads	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Slenderness	<input checked="" type="checkbox"/>
Spiral Tie	<input checked="" type="checkbox"/>
ACI Factors	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 10:53PM, 26 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 980000 User: KW-0000001, Ver 5.8.0, 10-Sep-2003
 (c)1983-2003 ENERCALC Engineering Software Page 1
 c:\nc2\examples\con\Concrete Calc

Description Column with Applied End Moments

General Information Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Diameter	27.000 in	fc	3,000.0psi	Total Height	0.000 ft
Number of Bars	12	Fy	60,000.0 psi	Unbraced Length	21.000 ft
Bar Size	8	Seismic Zone	4	Eff. Length Factor	1.000
Total Rebar Area	9.480 in ²	LL & ST Loads Act Separate		Column is BRACED	
Rebar Percent	1.656 %	Spiral Ties Used			
Bar Cover	2.500 in				

Loads

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design. Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

	Dead Load	Live Load	Short Term	Eccentricity
Axial Loads	161.500 k	121.200 k	42.500 k	6.000 in
Applied Moments...				
@ Top	31.000 k-ft	26.000 k-ft	5.100 k-ft	
@ Bottom	31.000 k-ft	26.000 k-ft	5.100 k-ft	

Summary Column is OK

Column Diameter= 27.00in, with 12 #8 Bars

	ACI C-1	ACI C-2	ACI C-3
Applied Pu : Max Factored	432.14 k	285.60 k	204.85 k
Allowable Pn * Phi @ Design Ecc.	797.85 k	797.85 k	797.85 k
M-critical	216.07 k-ft	142.80 k-ft	102.42 k-ft
Combined Eccentricity	6.0000 in	6.0000 in	6.0000 in
Magnification Factor	1.00	1.00	1.00
Design Eccentricity	6.0000 in	6.0000 in	6.0000 in
Magnified Design Moment	216.07 k-ft	142.80 k-ft	102.42 k-ft
Po * .80	1,703.95 k	1,703.95 k	1,703.95 k
P : Balanced	677.52 k	677.52 k	677.52 k
Ecc : Balanced	10.8365 in	10.8365 in	10.8365 in

Slenderness per ACI 318-02 Section 10.12 & 10.13

Actual k Lu / r	37.333	Elastic Modulus	3,122.0 ksi	Beta	0.850
		ACI Eq. C-1	ACI Eq. C-2	ACI Eq. C-3	
Neutral Axis Distance	18.4735 in	18.4735 in	18.4735 in		
Phi	0.7500	0.7500	0.7500		
Max Limit M/r	37.3289	37.1369	37.0588		
Beta = M.sustained/M.max	0.5232	0.7917	0.7095		
Cm	0.4890	0.4954	0.4960		
EI / 1000	21,613.24	18,374.79	19,257.48		
Pc : pi^2 EI / (k Lu)^2	3,359.07	2,855.76	2,992.94		
alpha: MaxPu / (.75 Pc)	0.1715	0.1333	0.0913		
Delta	1.0000	1.0000	1.0000		
Ecc: Ecc Loads + Moments	6.0000	6.0000	6.0000 in		
Design Ecc = Ecc * Delta	0.0000	0.0000	0.0000 in		

ACI Factors (per ACI 318-02, applied internally to entered loads)

ACI C-1 & C-2 DL	1.400	ACI C-2 Group Factor	0.750	Add'l "1.4" Factor for Seismic	1.400
ACI C-1 & C-2 LL	1.700	ACI C-3 Dead Load Factor	0.900	Add'l "0.9" Factor for Seismic	0.900
ACI C-1 & C-2 ST	1.700	ACI C-3 Short Term Factor	1.300		
....seismic = ST *	1.100				

Spiral Tie Requirements per 97 UBC 1910.9.3

Spiral Tie Bar Size #	3	Min. Spiral Reinforcement Ratio	0.011
Gross Area of Column	572.55 in²	Max Spiral Tie Spacing	1.756 in
Core Area Within Spirals	380.13 in²		

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title : ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 10:53PM, 26 OCT 03
 Description : Collection of example problems
 Scope : All programs in the Structural Engineering Library

Rev: 000000
 User: KW-0000001, Ver 5.6.0, 10-Sep-2003
 (c)1983-2003 ENERCALC Engineering Software

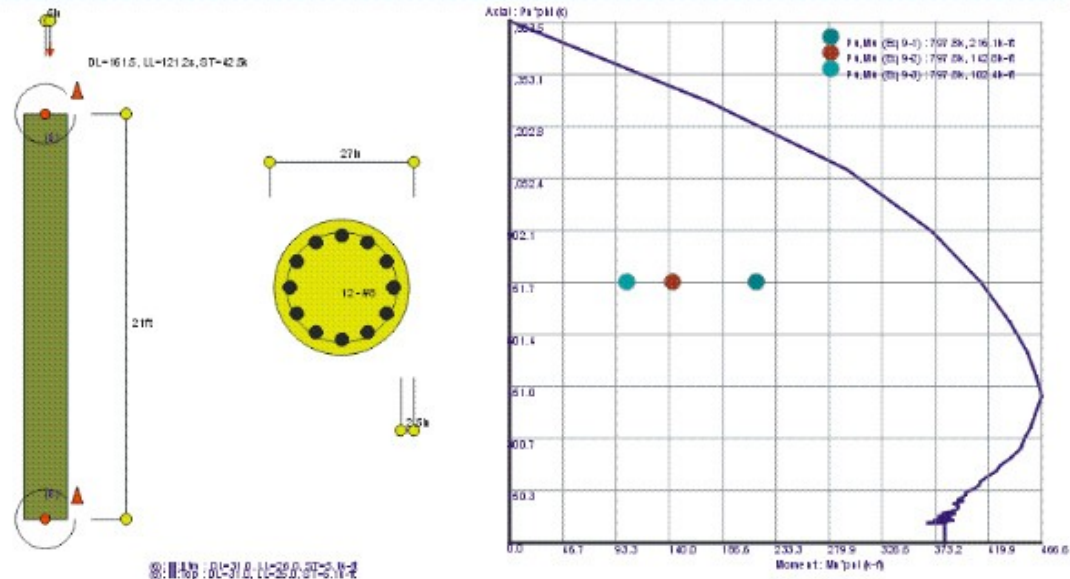
Circular Concrete Column

Page 2

www.enercalc.com/Concrete/Calcs

Description Column with Applied End Moments

Sketch & Diagram



2.5 Tilt-Up Wall Panel

This program provides design investigation for a one foot wide strip of concrete wall panel subjected to axial and lateral loads due to wind or seismic forces. Six different design methods may be specified which cover the typical design philosophies for tilt-up wall panels. These methods combine vertical and lateral loads to calculate wall moments and deflections.

The differences in the design methods center around the moment of inertia used to calculate wall deflections, and exactly how the maximum wall deflection is obtained. The methods include:

- Analysis according to section 2614(i) of the Uniform Building Code. This method is based upon tests performed by a committee of the Structural Engineers Association

of Southern California.

- Analysis using ACI equation 9-7 to calculate moment of inertia. This simplified equation yields a conservative moment of inertia. Analysis using this moment of inertia can either iterate wall deflections to convergence, or directly calculate wall deflection at the maximum moment capacity.
- Analysis using ICRACKED for the full height of the wall, and is very conservative. Analysis using this moment of inertia can either iterate wall deflections to convergence, or directly calculate wall deflection at the moment capacity of the wall.

Along with these different analysis methods, you can include the effects of fixity at the base of the wall (for dock-high walls) and wind or seismic load on a projecting parapet.

In addition to eccentric roof dead and live loads, you can apply axial loads to the top of the wall, simulating loads due to a wall section above. The program also allows point and distributed loads to be applied laterally to the panel strip, giving you the capability to design narrow jambs beside openings.

Each time the program is recalculated, both seismic and wind loads are used to determine service and factored moments and deflections. Results include moment capacity, applied moments at mid-height and at top of wall, actual and allowable axial stress, reinforcement ratio, height/deflection ratio, and height/thickness ratio.

The screenshot shows the ENERCALC Tilt-Up Wall Panel Design software interface. The window title is "ENERCALC c:\EC95\EXAMPLES.EC95 - Tilt-Up Wall Panel Design". The interface is divided into several sections:

- General Settings:**
 - Description: Flat wall strip w/ wind load
 - Clear Height: 26.000 ft
 - Parapet Ht.: 3.500 ft
 - Thickness: 6.00 in
 - Bar Size: 5
 - Bar Spacing: 16.00 in
 - Bar Depth: 3.500 in
 - Analysis Method: UBC Slender Wall (selected), ACI 318-02, Empirical
 - Seismic Zone: 4
 - Adjust Moment When Thk/2 <=> Bar Depth?:
 - fc: 3,000.0 psi
 - Fy: 60,000.0
 - Phi: 0.900
 - Concrete Wt: 145.00 pcf
 - Min Vert Steel %: 0.0020
 - Min Horiz Steel %: 0.0012
 - Strip Width: 12.00 in
 - Min Defl. Ratio: 150.00
- Results:**
 - For Factored Load Stresses:**

	Seismic	Wind
Basic Defl w/o P-Delta	0.452	0.285 in
Basic Moment w/o P-Delta	30,212.26	19,031.14 in-#
Moment Excess of M _{cr}	25,741.04	10,994.88 in-#
Max. P-Delta Deflection	7.800	7.968 in
Max P-Delta Moment	45,459.06	30,712.89 in-#
 - For Service Load Deflections:**

	Seismic	Wind
Basic Defl w/o P-Delta	0.323	0.224 in
Basic Moment w/o P-Delta	21,590.19	14,983.74 in-#
Moment Excess of M _{cr}	4,766.37	0.00 in-#
Max. P-Delta Deflection	1.417	0.224 in
Max P-Delta Moment	24,484.39	17,887.94 in-#
 - Maximum Allow Vertical Bar Spacing: 18,000 in
 - Maximum Allow Horizontal Bar Spacing: 18,000 in
 - Parapet Bar Spacing Req'd : SEISMIC: 18,000 in
 - Parapet Bar Spacing Req'd : WIND: 18,000 in

Basic Usage

- Wall Data defines the overall wall geometry. Clear Height is the distance the wall panel strip spans from points of lateral support, typically between floor and roof diaphragm. Parapet Height is actually used as a cantilever, applying additional vertical loads and moments to the top of the wall. Wall thickness and rebar size and spacing control the strength of the wall, and are the items you can easily change to achieve a satisfactory design.
- Concrete Weight is used to generate lateral and vertical loads due to the walls own weight. Maximum Deflection ratio is typically a code specified limit on the clear span/deflection allowable.
- Design Data allows you to define the items that specify the load combinations and factors used. Phi is entered to reflect the actual construction quality, and not a calculated value (this procedure is typical of many codes, with Phi being set to 0.72 for uninspected and 0.90 for inspected construction). The Seismic Factors for both wall and parapet can be entered to create the lateral seismic loads to a wall panel strip. If you choose to Include the Parapet in the analysis, the lateral wind and seismic loads acting on the parapet will counteract the lateral loads below.
- Lateral Loads can be applied to the wall in addition to the automatically generated seismic loads. Wind Load analysis is always performed with each recalculation. Point and Uniform Lateral Loads can be applied to the panel strip to represent lateral load contributed from the concrete area above an adjacent opening (e.g: a lintel), and should be entered as unfactored loads (but with seismic factor already used to reduce the actual wall weight).
- Vertical Loads from a roof or floor can be applied to the wall, either concentrically or eccentrically as from a ledger.
- You can Choose Design Methods according to your own personal design theory preference. The methods basically allow you to vary the moment of inertia used to calculate deflections, and the method used to obtain maximum deflections. These choices are based on the design theories the SEAOSC Yellow and Green book methods, the UBC section 2614(i) procedure, and adaptation of ACI equation 9-7 to P-Delta analysis.
- For each method, both wind and seismic load analysis are performed. Applied and generated vertical and lateral loads are factored and used to generate moment diagrams at 250 span increments along the clear height. Depending on the design method chosen, the deflections will then be iterated using P-Delta moments until deflection convergence occurs.
- Because the program:
 - Allows fixity at the base of the wall.
 - Allows the parapet moments to reduce bending between supports, and
 - Allows added lateral point and uniform loads,
- the standard methods of calculating moments at mid-height are not used. Instead, full deflection iteration is performed and all 250 span increments searched for maximum deflection and bending values. Enough detail is provided for the user to review all section analysis values, service load level deflection calculations, and factored load ultimate moment calculations.
- By repeatedly modifying wall thickness and rebar size and spacing, you can quickly generate an economical wall panel strip design to conform to deflection limits,

strength capacity, allowable axial stress, and acceptable reinforcing percentages.

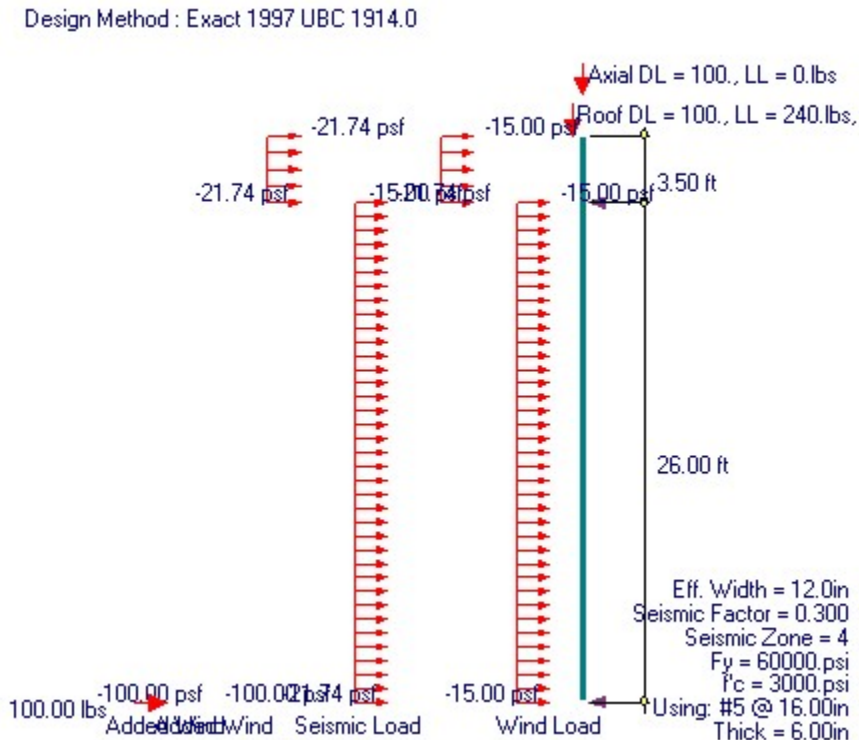
- When your design is complete, Print or Save the data from your calculation, Reset the calcsheet to begin another wall design, or use the Access Menu to use another program.

Unique Features

- By supplying six different design methods, virtually all recognized design methods are available for use.
- The actual moment and deflection of the wall is calculated by going through a series of iterations as the wall increasingly deflects laterally. The analysis is performed for 250 points along the wall's span.
- Both wind load and seismic loads are evaluated side by side for quick determination of governing cases.
- User may specify Phi factor to represent different special inspection conditions.
- Program computes both service load deflection and factored moments.
- Assumptions & Limitations
- For lateral design of jamb strips or piers between openings, the user can determine the pro-rated lateral load on the strip of wall by multiplying the seismic factor by the ratio: $(\text{Tributary Load} / \text{Actual Load}) * \text{Code Specified Seismic Factor}$

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General		Loads	ACI Factors
Description		Flat wall strip w/ wind load	
Clear Height		26.000	ft
Parapet Ht.		3.500	ft
Thickness		6.00	in
Bar Size		5	
Bar Spacing		16.00	in
Bar Depth		3.500	in
Analysis Method			
	Non-Iterated	Iterated	
UBC Slender Wall	<input checked="" type="radio"/>	<input type="radio"/>	
ACI 318-02	<input type="radio"/>	<input type="radio"/>	
Empirical	<input type="radio"/>	<input type="radio"/>	
Seismic Zone		4	
Adjust Moment When Thk/2 <=> Bar Depth ? <input type="checkbox"/>			
fc	3,000.0	psi	Min Vert Steel %
			0.0020
Fy	60,000.0	\$\$\$\$\$	Min Horiz Steel %
			0.0012
Phi	0.900		Strip Width
			12.00 in
Concrete Wt	145.00	pcf	Min Defl. Ratio
			150.00

Clear Height

Enter the distance between lateral supports for the wall. This is typically between the floor slab and attached floor and/or roof diaphragm.

Parapet Height

This height is an extension of the wall above the top support, and will be treated as a cantilever when lateral seismic and wind loads are applied. This will tend to reduce the moment and deflection between supports by applying an opposite concentrated moment at the top support.

Thickness

Wall thickness to be used in design analysis. This thickness will be used to calculate wall weight for vertical and lateral loads. When there are recessed reveals in the wall for architectural treatment, enter the gross thickness here and modify the reinforcing depth to center the rebar in the net panel thickness.

Bar Size

Enter the rebar size for vertical bars.

Bar Spacing

This indicates the horizontal spacing of the vertical reinforcement entered above.

Bar Depth

Enter the depth to the reinforcing steel. This depth will be used to determine moment capacity and moment of inertia.

Analysis Method

In this section, the user specifies one of six design methods to be used throughout the calculation.

- **1989 UBC 2614(i) Exact, Non-Iterated** This selection follows the UBC section 2614(i) method almost exactly for calculating deflections and moments. The method is non-iterative; the wall deflection used for P-Delta is calculated as the maximum deflection of the wall when it reaches failure. When we say follows almost exactly, we mean that the code does not mention that the maximum moment is never at the wall mid-height, doesn't consider partial length, moment, or point lateral loads, nor does it consider base fixity. This method is the formal code adaptation of the Green Book published by the Structural Engineers Association of Southern California, and was the result of an extensive testing program. This method goes beyond the UBC simplifications to include partial length lateral loads, lateral point loads, and any degree of base fixity.
- **b** This method is the same as above EXCEPT that deflections are iterated to calculate maximum wall deflections and moments. This is the most common of the six methods used.
- **ACI Eq. 9-7 Iterate** This method uses ACI equation 9-7 to calculate the moment of inertia for the entire wall. Starting with a deflection due only to lateral wind or seismic on the wall, deflections are repeatedly iterated and the increased moment due to P-Delta effects added to create still greater moments.
- **ACI Eq. 9-7 Mx. Defl.** This method uses ACI equation 9-7 to calculate moment of inertia, but uses a deflection that would result if the wall were about to fail from applied uniform loads. This yields the maximum possible deflection that could ever occur in the wall, which is then used to calculate a P-Delta moment.
- **Using ICR Full Height Iterate** This method is very conservative, using only ICRACKED for deflection calculations. Starting with a deflection due only to lateral wind or seismic on the wall, deflections are repeatedly iterated and the increased moment due to P-Delta effects added to create still greater moments.
- **Using ICR Full Height Max. Defl.** This method uses ICRACKED for the entire wall and uses a deflection that would result if the wall were about to fail from applied uniform loads. This yields the maximum possible deflection that could ever occur in the wall. This is the most conservative method of the five, and results in highly reinforced walls.

Adjust Moment when Thickness/2 <> Bar Depth

This flag tells the software whether to decrease the moment capacity of the wall section by the

internal moment produced when the rebar is not at the center of the wall. This is not common but some engineers do prefer to take this into consideration.

Normally the allowable moment would be calculated as:

$$M_n = A_s \cdot \text{eff} \cdot F_y \cdot (d - a/2)$$

When this flag is checked then:

$$M_n = A_s \cdot \text{eff} \cdot F_y \cdot (d - a/2) - P_u \cdot (\text{WallThk} / 2 - \text{Bar Depth})$$

f_c

Enter the 28 day compressive strength of concrete to be used.

F_y

Enter the allowable yield stress of the reinforcing to be used.

Phi

The user can enter a value for Phi (capacity reduction factor) for design. Typically .9 is used for inspected construction, 0.72 for uninspected. Most codes now do not allow uninspected values.

Concrete Weight

Enter the concrete density to be used for calculation of vertical and seismic loads.

Minimum Vertical Steel Percentage

Specify the minimum allowable percentage of vertical reinforcing for the wall. This will be used to determine the Maximum Vertical Spacing.

Minimum Horizontal Steel Percentage

Specify the minimum allowable percentage of horizontal reinforcing for the wall. This will be used to determine the Maximum Vertical Spacing.

Strip Width Used for Analysis

This does an analysis using a vertical "Strip" of wall that is used to carry the vertical and lateral loads. By default this strip is 12" wide. If you have a larger width of wall, perhaps next to a door opening that is 18" wide, you can enter that dimension in here. The program will divided the applied point vertical and lateral loads over this distance.

Minimum Deflection Ratio

This is the minimum allowable ratio of Clear Height/Service Load Deflection.

Loads / Vertical Loads Tab

General	Loads	ACI Factors
Vertical Loads Lateral Loads		
Vertical Loads...		
<i>Note! These Loads Applied to "Strip Width".</i>		
Uniform DL	<input type="text" value="100.00"/>	#/ft
Uniform LL	<input type="text" value="240.00"/>	#/ft
...eccentricity	<input type="text" value="6.500"/>	in
Concentric DL	<input type="text" value="100.0"/>	lbs
Concentric LL	<input type="text"/>	lbs
Combine LL w/ Short Term	<input type="checkbox"/>	
Moment of Inertia Magnifiers		
Seismic "I" Magnifier	<input type="text" value="1.00"/>	
Wind "I" Magnifier	<input type="text" value="1.00"/>	
<i>(Please leave both = 1.0 unless you are sure !)</i>		

Uniform Loads

This represents the vertical load applied to the wall in addition to wall weight, and will be applied at the eccentricity from the wall centerline as specified. When using an eccentricity it will always be additive to the moment between supports.

Concentric Loads

This represents the vertical load applied to the wall in addition to wall weight. The program will apply it at the wall centerline, assuming no eccentricity. This load input is supplied in cases where significant load is being supported by the wall.

Combine Live Load with Short Term

The designer must specify whether the applied live load should be combined with the dead load when evaluating the design. Typically when wind load governs it should be included.

Moment of Inertia Magnifiers

These items are rarely used. To explain their purpose picture a tilt-up wall panel with a tall large opening. The jamb width is 24" for 3/4 of the walls height BUT the top 1/4 will be stiffened by the large concrete area above the opening.

By examination it is obvious that the jamb strip will be slightly stiffer because of this effect. When you would like to see the effect a higher moment of inertia (stiffer) jamb strip would have on the calculated P-Delta moments you can enter a value here to be applied DIRECTLY to the calculated effective moment of inertia of the wall strip being used.

Loads / Lateral Loads Tab

General		Loads		ACI Factors	
Vertical Loads		Lateral Loads			
Wall : '94 UBC Seismic Factor Z Ip Cp -or- Similar 2003 IBC Factor Divided by 1.4		<input type="text" value="0.300"/>			
Parapet : '94 UBC Seismic Factor Z Ip Cp -or- Similar 2003 IBC Factor Divided by 1.4		<input type="text" value="0.300"/>			
Lateral Loads...					
Wind Load	<input type="text" value="15.00"/>	psf			
Point Lateral Load <i>(Applied to full "Pier Width")</i>	<input type="text" value="100.00"/>	lbs			
...height	<input type="text" value="0.000"/>	ft			
...load type	<input type="radio"/> Seismic <input checked="" type="radio"/> Wind				
Uniform Lateral Load <i>(Applied to full "Pier Width")</i>	<input type="text" value="100.00"/>	#/ft			
...distance to top	<input type="text" value="0.000"/>	ft			
...distance to bot	<input type="text" value="0.000"/>	ft			
...load type	<input type="radio"/> Seismic <input checked="" type="radio"/> Wind				
Use Lateral Parapet Wt ?	<input checked="" type="checkbox"/>				

Wall Seismic Factor

Enter the seismic factor to be applied to the wall weight for lateral loading. If you have calculated a seismic factor from the 1997 UBC or IBC that is an "Ultimate" value divide it by 1.4 before entering it here to get it to a service load level.

Parapet Seismic Factor

Enter the seismic factor to be applied to the parapet weight for lateral loading. If you have calculated a seismic factor from the 1997 UBC or IBC that is an "Ultimate" value divide it by 1.4 before entering it here to get it to a service load level.

Wind Load

Enter the wind load in PSF that should be applied to the wall.

Point lateral Load

This load is applied to the 12" wide strip of wall in addition to the lateral load due to wind or seismic forces. It should be entered AFTER APPLYING A SEISMIC FACTOR. This additional lateral load is intended to enable the user to model a section of wall or jamb strip when additional loads are applied

to it.

For example, due to an adjacent lintel cast integrally with the wall which spans vertically between roof and a horizontal bond beam at the head of the opening.

This load is factored using ACI factoring for wind and seismic loads, depending upon your entry for Type: Wind/Seismic.

...height

Enter the distance from the bottom of the wall to the point of application of the concentrated point load.

...load type : Seismic/Wind

This specifies whether this added load is due to seismic or wind forces. It is needed so that the ACI load factors can include the additional 1.1" factor for seismic forces.

Uniform Lateral Load

This load is applied to the analysis of wall in addition to the lateral load due to wind or seismic forces. It should be entered AFTER APPLYING A SEISMIC FACTOR, if this is the case. This additional lateral load is intended to enable the user to model a section of wall or jamb strip when additional loads are applied to it, for example due to a horizontally spanning lintel cast integrally with the wall.

Distance to Top

Enter the distance from the bottom of the wall to the upper end of the uniform lateral load. Please be sure to limit this input to a maximum of Clear Height, as the program cannot apply this load above the top support.

Distance to Bottom

Enter the distance from the bottom of the wall to the start of the uniform lateral load.

...Load Type : Seismic/Wind

This specifies whether this added partial length uniform load is due to seismic or wind forces, needed so that the ACI load factors can include the additional 1.1 needed for seismic forces.

Use Lateral Parapet Weight ?

This YES/NO flag specifies whether the parapet lateral wind and seismic load should be used.

Answering YES will generate moments at the top of the wall that will decrease the maximum moments between supports.

ACI Factors

This tab specifies the load factors to be used by the program when calculating the factored dead, live, and short term loads to be used in the internal load combinations for determining M_u for the wall.

General	Loads	ACI Factors
Load Factors (Nomenclature per ACI 318-02 Appx C)		
ACI C-1 & C-2 Dead		<input type="text" value="1.400"/>
ACI C-1 & C-2 Live Load		<input type="text" value="1.700"/>
ACI C-1 & C-2 Short		<input type="text" value="1.700"/>
...seismic = ST * :		<input type="text" value="1.100"/>
ACI C-2 Group Factor		<input type="text" value="0.750"/>
ACI C-3 Dead Load Factor <i>used in C-1, C-2, and C-3</i>		<input type="text" value="0.900"/>
ACI C-3 Short Term Factor		<input type="text" value="1.300"/>
Additional load factors for Seismic Zone 3 & 4		
"1.4" Factor		<input type="text" value="1.400"/>
"0.9" Factor		<input type="text" value="0.900"/>

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results / Summary Tab

Results | Sketch | Printing

Summary | Wall Analysis | Analysis Data | Add'l Values

Wall Design OK

Factored Load Bending Analysis : Seismic Load Governs
 Maximum Iterated Moment : Mu 45,459.06 in-#
 Moment Capacity : Mn * Phi 46,379.95 in-#

Service Load Deflection Analysis : Seismic Load Governs
 Maximum Iterated Deflection 1.417 in
 Deflection Limit (Using Specified Ratio) 2.080 in

	Seismic	Wind
Mn * Phi : Moment Capacity	46,379.95	44,405.94 in-#
Applied: Mu @ Mid-Span	45,459.06	30,712.89 in-#
Applied: Mu @ Top of Wall	5,332.07	2,088.19 in-#
Fa : Actual	19.39	19.39 psi
Fa : Allowable	120.00	120.00 psi
Actual As %	0.0055	0.0055
UBC Allow. As % = 0.6 * RhoBal	0.0128	0.0128
Maximum Service Load Deflection	1.42	0.22 in
Service Ht/Deflection Ratio	220 :1	1,390 :1

Factored Load Bending Analysis

The results here are the maximum governing moments in the wall panel strip after an iterated P-Delta calculation is performed to include the effect of additional moments induced from the lateral bending of the wall.

Maximum Iterated Moment

Using the design method specified, the factored loads are applied to the wall and deflections used to calculate maximum moments due to bending from the seismic or wind loads, added lateral loads, and P-Delta moments. This value is the Maximum Moment from P-Delta Analysis

Moment Capacity : Mn * Phi

This wall capacity is calculated using wall thickness, reinforcing, and includes the effect of axial load to increase the effective area of tension reinforcement. Since axial load can vary between seismic and live load conditions, the ultimate moment capacity must be calculated for both cases.

Service Load Deflection Analysis

The results here use service loads applied to the wall in an iterative P-Delta analysis until deflection convergence is reached where the moment is no longer increasing.

Maximum Iterated Deflection

This is the maximum calculated wall panel deflection due to service loads for the design method specified. A method that calculates deflections at the moment capacity of the wall will give far greater deflections than for an iterated solution.

Deflection Limit

This is the maximum allowable wall panel deflection calculated by entering the user defined "Max. Defl. Ratio" times the clear span of the wall.

Mn * Phi : Moment Capacity

The capacity of the wall for seismic and wind conditions is shown. These values are different because of the different components of vertical loads that contribute to design strength.

Applied Mu @ Mid-Span & Top of Wall

This is a breakdown of the four calculated ultimate moments in the wall panel. Moments are calculated at the top of the wall due to eccentric vertical loads and lateral parapet loads and also at the mid-span for both wind and seismic loadings.

Fa:Actual

This stress equals the vertical dead and live loads above mid-height. These loads are divided by Wall Thickness * 12 inches. For the UBC method, this stress should be limited to 0.04f'c.

Fa:Allowable

For the UBC method, the allowable axial stress is limited to 0.04f'c. This value will not apply when the other methods are being used.

Actual As %

When the UBC method is used, the maximum allowable steel percentage is limited to 0.6 times the balanced percentage.

Results / Wall Analysis Tab

This tab lists the results for the factored load moment analysis and the service load deflection analysis.

Results Sketch Printing		
Summary Wall Analysis Analysis Data Add'l Values		
For Factored Load Stresses	<u>Seismic</u>	<u>Wind</u>
Basic Defl w/o P-Delta	0.452	0.285 in
Basic Moment w/o P-Delta	30,212.26	19,031.14 in-#
Moment Excess of M _{cr}	25,741.04	10,994.88 in-#
Max. P-Delta Deflection	7.800	7.968 in
Max P-Delta Moment	45,459.06	30,712.89 in-#
For Service Load Deflections	<u>Seismic</u>	<u>Wind</u>
Basic Defl w/o P-Delta	0.323	0.224 in
Basic Moment w/o P-Delta	21,580.19	14,983.74 in-#
Moment Excess of M _{cr}	4,766.37	0.00 in-#
Max. P-Delta Deflection	1.417	0.224 in
Max P-Delta Moment	24,484.39	17,887.94 in-#
Maximum Allow Vertical Bar Spacing		18.000 in
Maximum Allow Horizontal Bar Spacing		18.000 in
Parapet Bar Spacing Req'd : SEISMIC		18.000 in
Parapet Bar Spacing Req'd : WIND		18.000 in

Basic Defl. & Deflection w/o P-Delta

This is the calculation of wall deflections and moments without any moment magnification from P-Delta effects. Only lateral seismic load, applied lateral load, and moments due to axial load eccentricity are applied in using a standard beam analysis.

Moment in excess of M_{cr}

This value is the moment in excess of M_{cracked} (which is the moment capacity of the wall when cracking in the tension region starts). This excess value is used in the calculation of the added deflections.

Max P-Delta Deflection & P-Delta Moment

This is the maximum calculated deflection of the wall after iterating P-Delta effects until there is no further increase in moment.

Maximum Allowable Bar Spacing

These spacing values are the result of applying the "Min. Steel %" entered on the "General" tab to the wall thickness.

Parapet Bar Spacing

This is the maximum required spacing of the bar size you specified for the wall when examining the moment at the top of the wall due to wind or seismic loads on the parapet.

Results / Analysis Data Tab

This tab shows various calculated values that are used in the wall analysis.

Results Sketch Printing		
Summary Wall Analysis Analysis Data Add'l Values		
E	3122,018.6	psi
n = Es / Ec	9.29	
Ht / Thk Ratio	52.00	
Sgross	72.000	in ³
Fr Multiplier for sqrt(f'c)	<input type="text" value="5.00"/>	
Fr =	273.86	psi
Mcr = S * Fr	19,718.0	in-#
Rho: Bar Reinf Pct	0.0214	
Values for Mn Calculation...	<u>Seismic</u>	<u>Wind</u>
As:eff= [Pu:tot + AsFy]/Fy	0.265 in	0.257 in
a : (AsFy + Pu)/(.85 fc b)	0.520 in	0.504 in
c = a / .85	0.611 in	0.593 in
Igross	216.000 in ⁴	216.00 in ⁴
Icracked	21.46 in ⁴	21.01 in ⁴
I-eff (ACI methods only)	0.00 in ⁴	0.00 in ⁴
Phi: Capacity Reduction	0.900	0.900
Mn = As:eff Fy (d - a/2)	51,533.27 in-#	49,339.94 in-#

E

The modulus of elasticity for concrete is calculated as:

$$E_c = 57,000 * f'_c^{1/2}$$

n

This is the ratio of Steel/Concrete elastic modulus. See later in this section for formula used to calculate "E".

Ht / Thickness Ratio

This calculated value is a commonly referenced value that designers use to establish a panel's

thickness. It is equal to the Clear Height/Wall Thickness.

S-gross

Gross section modulus for 12" of wall width:
 $12" * (\text{Wall Thickness})^2 / 6$

Fr

The modulus of rupture is calculated by: $Fr = 5 * f'c^{1/2}$

Mcr

The moment capacity of the gross wall section equals the gross section modulus times the modulus of rupture.

Rho Balanced

This represents the balanced steel area required for simultaneous steel yield and 0.003 in concrete strain. This value will be used to calculate the maximum allowable steel percentage by the UBC method.

As (eff)

The effective area of steel used to calculate moment capacity and section properties is listed here. The area of steel reinforcing is increased to take into account the effect of compression on the section.

a

This is the typical ACI equation for determining the depth of the equivalent compressive stress block used for analysis.

c

This is the true compressive stress block depth calculated from the strain compatibility equations, letting concrete strain = .003 in and steel strain equals yield strain.

I-gross

Gross moment of inertia for 12" of wall width:
 $12" * (\text{Wall Thickness})^3 / 12$

I-cracked

The moment of inertia for 12" of wall width, considering a Cracked Section is taken as :
 $I_{cr} = n * A_s(\text{eff}) * (d-c)^2 + (4 * c^3)$

I-effective (Used for ACI methods only)

By using ACI equation 9-7 and the unfactored simple span and P-Delta applied moment, the effective moment of inertia to be used in calculating the wall deflections is obtained. When iteration is specified, this moment of inertia will converge closer to ICRACKED as the wall increasingly deflects outward. When deflection at moment strength is specified, Mn is used to calculate IEFFECTIVE.

Phi

This capacity reduction factor is applied to the calculated moment capacity to take into account such factors as quality control, use, and design/analysis assumptions. This value is a restatement of the Phi value entered under the sub-section Design Data.

Mn

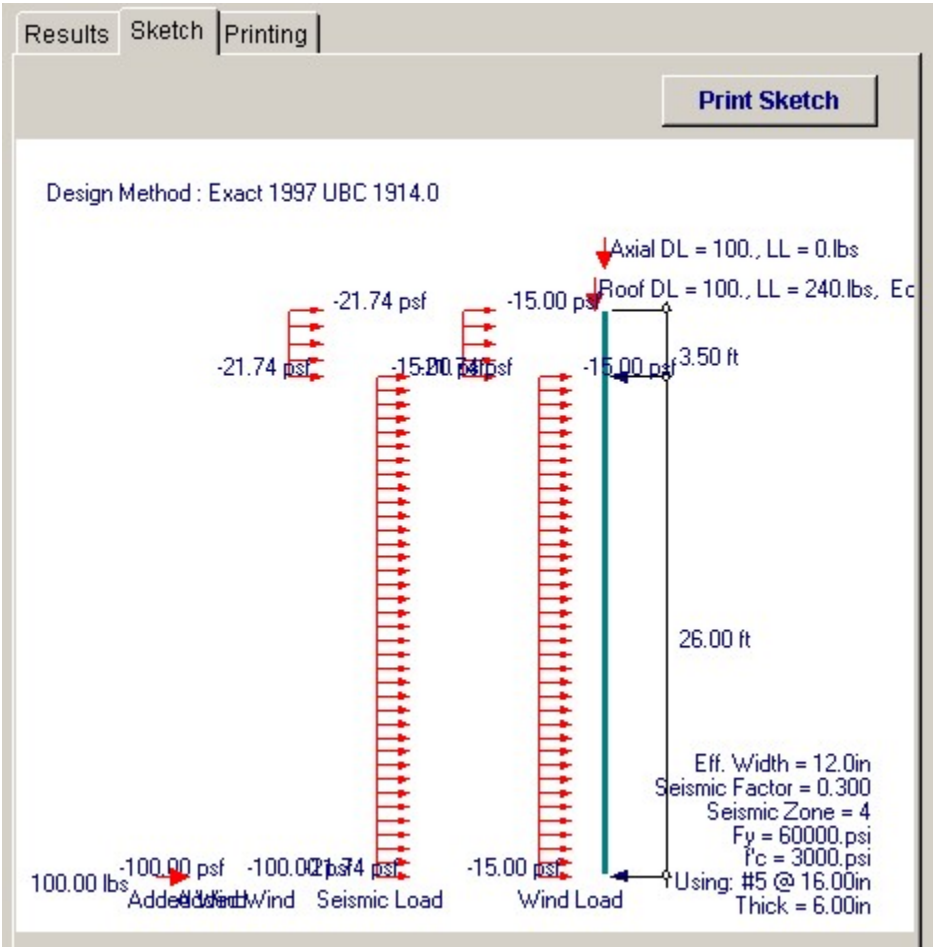
This is the calculated maximum moment capacity of the section whose values for allowable stresses, reinforcing size and spacing, and effective area of steel.

Results / Additional Values Tab

Results Sketch Printing		
Summary Wall Analysis Analysis Data Add'l Values		
Loads used for analysis		
Wall Weight		72.500 psf
Wall Wt * Wall Seismic Factor		21.750 psf
Wall Wt * Parapet Seismic Factor		21.750 psf
Service Applied Axial Load		200.00 #/ft
Service Wall WT @ Max Mom Location		1,196.25 #/ft
Total Service Axial Loads		1,396.25 #/ft
	<u>Seismic</u>	<u>Wind</u>
Factored Applied Axial Load	280.00	210.00 #/ft
Factored Lateral Wall Weight	1,674.75	1,256.06 #/ft
Total Factored Lateral Loads	1,954.75	1,466.06 #/ft

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Loads	<input checked="" type="checkbox"/>
Wall Analysis	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Analysis Data	<input checked="" type="checkbox"/>
Additional Values	<input checked="" type="checkbox"/>
ACI Factors	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems **Job #** 97-000001
Dsgnr: MDB **Date:** 10:59PM, 26 OCT 03
Description: Collection of example problems
Scope: All programs in the Structural Engineering Library

Rev: 08/00/00
 User: K/W 09/00/01, Ver 6.8.0, 10-Sep-2003
 (c)1983-2003 ENERCALC Engineering Software

Tilt-Up Wall Panel Design

Page 1
 c:\ec55\examples\ec3\Concrete Calc

Description Flat wall strip w/ wind load

General Information Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Clear Height	26.000 ft	f _c	3,000.0 psi	Seismic Zone	4
Parapet Height	3.500 ft	F _y	60,000.0 psi	Min Vert Steel %	0.0020
Thickness	6.000 in	Phi	0.900	Min Horiz Steel %	0.0012
Bar Size	5	Width	12.000 in	Wall Seismic Factor	0.3000
Bar Spacing	16.000 in			Parapet Seismic Factor	0.3000
Bar Depth	3.500 in			LL & ST Not Combined	
Min Defl. Ratio	150.0				
Concrete Weight	145.00 pcf				

Using: UBC Sec. 1914.8 method...Exact, Non-Iterated
 Parapet Weight Counteracts Middle

Loads

Lateral Loads		Vertical Loads	
Wind Load	15.000 psf	Uniform DL	100.00 #/ft
Point Load	100.00 lbs	Uniform LL	240.00 #/ft
...height	ft	...eccentricity	6.500 in
...load type	Wind	Concentric DL	100.00 lbs
Lateral Load	100.00 #/ft	Concentric LL	lbs
...distance to top	ft	Seismic 'I' Magnifier	1.000
...distance to bot	ft	Wind 'I' Magnifier	1.000
...load type	Wind		

Note: Load factoring supports 2003 IBC and 2003 NFPA5000 by virtue of their references to ACI 318-02 for concrete design.
 Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

Wall Analysis

	For Factored Load Stresses		For Service Load Deflections	
	Seismic	Wind	Seismic	Wind
Basic Defl w/o P-Delta	0.452	0.285 in	0.323	0.224 in
Basic M w/o P-Delta	30,212.3	19,031.1 in-#	21,580.2	14,983.7 in-#
Moment Excess of M _{cr}	25,741.0	10,994.9 in-#	4,766.4	0.0 in-#
Max. P-Delta Deflection	7.800	7.968 in	1.417	0.224 in
Max P-Delta Moment	45,459.1	30,712.9 in-#	24,484.4	17,887.9 in-#
Maximum Allow Vertical Bar Spacing	18.000 in	Parapet Bar Spacing Req'd : SEISMIC		18.000 in
Maximum Allow Horizontal Bar Spacing	18.000 in	Parapet Bar Spacing Req'd : WIND		18.000 in

Summary **Wall Design OK**

26.00ft clear height, 3.50ft parapet, 6.00in thick with #5 bars at 16.00in on center, d= 3.50in, f_c = 3,000.0psi, F_y =
 Using: UBC Sec. 1914.8 method...Exact, Non-Iterated

Factored Load Bending	: Seismic Load Governs	Service Load Deflection	: Seismic Load Governs
Maximum Iterated Moment : Mu	45,459.06 in-#	Maximum Iterated Deflection	1.417 in
Moment Capacity	46,379.95 in-#	Deflection Limit	2.080 in

	Seismic	Wind
M _n * Phi : Moment Capacity	46,379.95 in-#	44,405.94 in-#
Applied: Mu @ Mid-Span	45,459.06 in-#	30,712.89 in-#
Applied: Mu @ Top of Wall	5,332.07 in-#	2,088.19 in-#
Max Iterated Service Load Deflection	1.42 in	0.22 in
Actual Deflection Ratio	220 : 1	1,390 : 1
Actual Reinforcing Percentage	0.0055	0.0055
UBC Allow. A _s % = 0.6 * R _{ho} Bal	0.0128	0.0128
Actual Axial Stress : (P _w + P _o) / A _g	19.39 psi	19.39 psi
Allowable Axial Stress = 0.04 * f _c	120.00 psi	120.00 psi

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Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 10:59PM, 26 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Description Flat wall strip w/ wind load

Analysis Data

E	3,122,018.6 psi	Sgross	72.000 in3
n = Es / Ec	9.29	Mcr = S * Fr	19,718.0 in-#
Fr Multiplier for sqrt(fc)	5.000	Fr =	273.86 psi
Ht / Thk Ratio	52.00	Rho: Bar Reinf Pct	0.0214
Values for Mn Calculation...			
As: eff = [Pu:tot + AsFy]/Fy		<u>Seismic</u>	<u>Wind</u>
a : (AsFy + Pu)/(.85 fc b)		0.265 in	0.257 in
c = a / .85		0.520 in	0.504 in
Igross		0.611 in	0.593 in
Icracked		216.000 in4	216.00 in4
I-eff (ACI methods only)		21.46 in4	21.01 in4
Phi: Capacity Reduction		0.00 in4	0.00 in4
Mn = As:eff Fy (d-a/2) - Pu (WallThk/2-Bar Depth)		0.900	0.900
		51,533.27 in-#	49,339.94 in-#

Additional Values

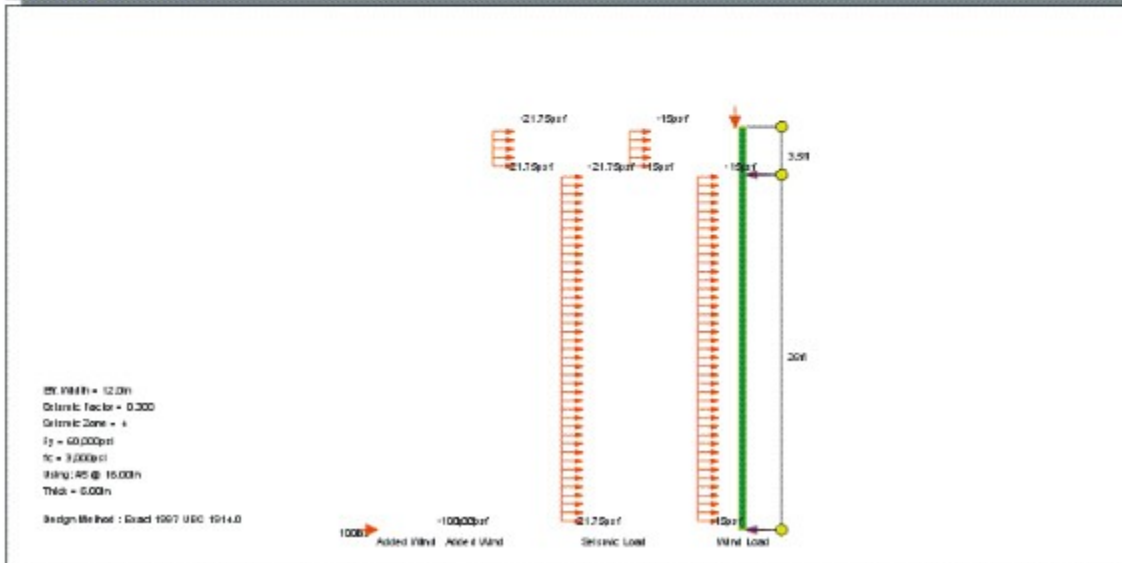
Loads used for analysis		Factored Loads	
Wall Weight	72.500 psf	Applied Axial Load	280.00
Wall Wt * Wall Seismic Factor	21.750 psf	Lateral Wall Weight	1,874.75
Wall Wt * Parapet Seismic Factor	21.750 psf	Total Lateral Loads	1,954.75
Service Applied Axial Load	200.00 #/ft		
Service Wt @ Max Mom	1,196.25 #/ft		
Total Service Axial Loads	1,396.25 #/ft		

ACI Factors (per ACI 318-02, applied internally to entered loads)

ACI C-1 & C-2 DL	1.400	ACI C-2 Group Factor	0.750	Add "1.4" Factor for Seismic	1.400
ACI C-1 & C-2 LL	1.700	ACI C-3 Dead Load Factor	0.900	Add "0.9" Factor for Seismic	0.900
ACI C-1 & C-2 ST	1.700	ACI C-3 Short Term Factor	1.300		
....seismic = ST * :	1.100				

FOOT RL = 100.0, LL = 240.0#, EOC = 6.00#

Sketch & Diagram



2.6 Shear Wall

This program provides complete vertical and lateral load design and analysis for concrete

shear walls up to five levels high. You can also design a rectangular footing supporting the wall, considering all moments, shears, and axial loads.

The program allows input of five different wall sections, each with its own base height, section height, length, offset, thickness, and material strengths. Up to ten lateral short-term loads and up to ten vertical dead, live, and short term loads can be applied to the entire wall system. The vertical and horizontal position of each load can be specified.

Concrete density and lateral weight factors can be entered to define the vertical weight and portion of vertical weight used as a generated lateral short-term load. This frees you of constantly recalculating vertical and lateral wall weights as you refine your wall and footing designs.

The program calculates shears and overturning forces for the base of each of the five wall sections, and determines required shear and bending reinforcement. Lateral loads are applied in each direction to determine the maximum moments (due to centerline offsets of portions of the wall above).

Each vertical load represents a concentrated load acting on the wall. This load is included in the shear design of the wall by providing an axial load which combines with the allowable shear equations. This load is included in the calculations for overturning moment on a wall section when it is eccentric to the centerline of the wall at that particular section.

The program also provides analysis and design capability for rectangular footings located under the wall. Total overturning forces are calculated about the bottom of the footing (with force due to wall weight included), and resultant service and factored load soil pressures are determined. The program automatically checks cases when the vertical resultant is outside the kern distance for soil pressure calculations. Also, overall overturning stability ratios are found.

A final calculation for one way shear stresses and moments at each end of the wall is performed by applying vertical loads only, vertical+lateral load to the left, and then to the right. Minimum reinforcement due to maximum moments is determined.

Basic Usage

- It is critical that the user understands the concept of the various ANALYSIS HEIGHTS which are used to define the bottom of each wall section. This provides the ability to have an analysis performed at any height above a datum. Also, when walls support more than five floors, the top of the wall lateral and vertical loads can be entered to apply the axial, shear, and moment loads from the elements above.
- General Data allows you to enter dimension and load combination data for the entire wall. Total Height specifies the top most height of the wall. Concrete Weight and Lat. Weight Factor define the vertical and lateral loads to use for automatic application of forces due to the wall's weight. You can specify whether to Include Live Load with short-term loads (typically not for seismic design), and set a minimum reinforcing area to be used for wall bending calculations.
- Lateral Loads are applied to all wall sections by specifying the load and height above the base level. This provides entry of simple point lateral loads to the wall, simulating a lumped diaphragm force. This load must not include ACI load factors, but any seismic factors should already have been applied to loads..
- Vertical Loads are applied to the wall by specifying the dead, live, and short-term components of each load. Each load has its own vertical and horizontal location which is used to calculate overturning moments and axial stress at each wall level.
- Analysis Height and Wall Thickness, Offset, and Length are entered to define the vertical and horizontal position of each of the five wall sections. You can also enter

the concrete and reinforcing strength of each section separately. Please see illustration above. Calculate the calcsheet and review the Story Shears, Moments, and Uplift at the ends of the base section. These values consider all vertical and lateral loads, including vertical and horizontal wall weights generated by the program.

- You can now review the Shear Analysis and Bending Analysis to determine if any changes need to be made in wall thicknesses or lengths to satisfy stress and reinforcing requirements.
- Continue to enter the Footing Design Values, which include material strengths, width, thickness, and projection beyond each end of the base wall section. Using these projections and the base wall length entered previously, factored load soil pressures, reinforcing requirements, and shear stresses will be calculated.
- To refine your Soil Pressures and Footing Design, modify the footing dimensions as necessary. The program will automatically calculate factored soil pressures, shears, and moments for ACI combination equations 9-1, 9-2, and 9-3 for lateral loads applied in both directions.

Unique Features

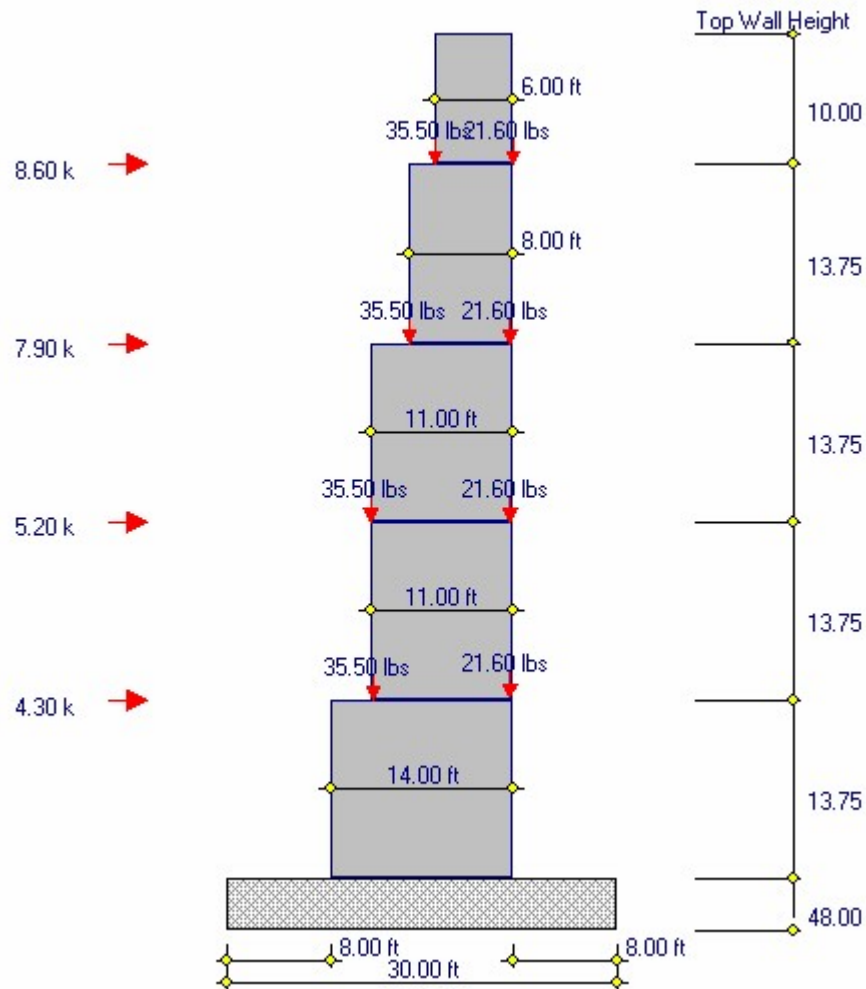
- This program provides a convenient method of designing a complete shear wall and footing system at once. The tedious task of estimating wall lengths, thicknesses, and footing size is performed in one step.
- This program can be used in instances where the designer must consider rigidities for multi-story structures with multiple shear walls that are all connected with a rigid diaphragm. This program can quickly provide excellent information for preliminary and final wall sizes.
- Vertical and lateral loads can be applied freely, and the lateral loads are applied in both directions to determine maximum moments, shears, uplift, and soil pressures.

Assumptions & Limitations

- Limited loadings are available, so loads should be combined and positions adjusted when more individual loads are acting than the program input permits.
- Wall weight is automatically calculated and added to the applied vertical loads and lateral loads.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General	Lateral Loads	Vertical Loads	ACI Factors	Footing	
Description 4 Story Wall with setbacks					
Total Wall Height	65.00 <input type="text"/> ft				
Concrete Weight	145.00 <input type="text"/> pcf				
Combine LL w/ ST Loads	<input checked="" type="checkbox"/>				
Wall : *94 UBC Seismic Factor Z Ip Cp -or- Similar 2003 IBC Factor Divided by 1.4	0.3000 <input type="text"/>				
Seismic Zone	4 <input type="text"/>				
Min Wall As% for Bending	0.0014 <input type="text"/>				
Overburden Weight	0.000 <input type="text"/> psf				
	<u>Bottom</u>	<u>2nd Level</u>	<u>3rd Level</u>	<u>4th Level</u>	<u>5th Level</u>
Analysis Ht	13.75 <input type="text"/>	27.50 <input type="text"/>	41.25 <input type="text"/>	55.00 <input type="text"/>	ft
Wall Offset (datum)	3.00 <input type="text"/>	3.00 <input type="text"/>	6.00 <input type="text"/>	8.00 <input type="text"/>	ft
Wall Length	14.00 <input type="text"/>	11.00 <input type="text"/>	11.00 <input type="text"/>	8.00 <input type="text"/>	6.00 <input type="text"/> ft
Wall Thickness	12.00 <input type="text"/>	12.00 <input type="text"/>	8.00 <input type="text"/>	8.00 <input type="text"/>	8.00 <input type="text"/> in
f'c : Concrete	3,000 <input type="text"/>	3,000 <input type="text"/>	3,000 <input type="text"/>	3,000 <input type="text"/>	3,000 <input type="text"/> psi
Fy : Rebar	60,000 <input type="text"/>	60,000 <input type="text"/>	60,000 <input type="text"/>	60,000 <input type="text"/>	60,000 <input type="text"/> psi
Effective Depth	11.20 <input type="text"/>	7.20 <input type="text"/>	6.40 <input type="text"/>	0.20 <input type="text"/>	0.20 <input type="text"/> ft

Total Wall Height

Enter the total height of the wall. This height is used by the program to determine the total height that the topmost Analysis Height wall section should extend to for determining the weight of that uppermost section.

Concrete Weight

Enter the unit weight of concrete that should be used for wall and footing weight calculations.

Include LL & ST

This entry instructs the program when to include live load with short-term loads. Typically, wind load analysis will include live loads, while short-term loads due to seismic forces are not combined with live loads.

Seismic Factor

This factor is applied to the weight of each wall section and the resulting force is applied laterally at the center of gravity of each wall. This should be used for seismic analysis only, and is commonly called the Seismic Factor which applies only to portions of structures.

Seismic Zone

This entry is used to control overall ACI load factoring. When wind loads generate the short-term forces, enter a 0" here. When seismic loads generate the short-term loads, enter 1" through 4" here to indicate the UBC seismic zone. When zone 3 or 4 is used, the special load factoring provisions of the UBC are applied. When 1 through 4 is used, this factor will be applied to the weight of each wall section and applied as a lateral load at the wall section centroid to account for the lateral seismic force created by the wall's own weight.

Min. Wall As % for Bending

This indicates the minimum wall reinforcement percentage to be used for determining bending reinforcement. Typically this will be set to 0.0025 (per ACI for shear walls).

Analysis Height

This is the user-defined height at which the analysis of a particular wall section will be performed. All moments, shears, and vertical loads at this height will be calculated using all applied lateral and vertical loads and the wall self weight above this point. The other wall data items specified in the calcsheet column will be used between this analysis height and the next higher level in the column to the right.

ALWAYS WORK WITH THE HIGHER ANALYSIS HEIGHT IN THE COLUMN TO THE RIGHT OF A LOWER HEIGHT. This is needed due to the manner in which the program calculates the heights by comparing heights of adjacent sections.

Wall Offset

Please refer to the diagram to further understand this item. Because this program can be used with a walls that have their length changes with height, you must enter the offset from the bottom wall section to the LEFT EDGE of the wall section. This enables the program to calculate the actual X-Distance to the center of gravity of the wall.

Wall Length

Enter the length to be used in the analysis of the particular wall section. Please note that if the Wall length + Offset is greater than the Wall Length + Offset for the level below, this indicates that the section OVERHANGS the section below it. This is not allowed.

Wall Thickness

Enter the thickness to be used in the analysis of a particular wall section. This thickness will be used only between the Analysis Height for that section up to the analysis of the next higher section (or Total Wall Height if it is the highest section).

f'c

Enter the concrete compressive strength to be used in the wall calculation for a particular wall section. This does not apply to the footing, which has it's own input area for material strengths.

Fy

Enter the steel yield stress for the reinforcing to be used in the wall analysis. Please note that this value applies to BOTH shear and moment reinforcing.

d :Effective Depth

The program considers the effective shear length of the wall to be $0.8 * \text{wall length}$. If you leave this entry blank, it will be filled in for you by the program.

Lateral Loads Tab

Enter the unfactored lateral loads applied to the wall. Do not apply load factors to this number; it should represent the actual lateral load for design loads (apply seismic factor to gravity loads BEFORE entering). The Height entry will specify the height at which the load is applied to the overall wall system above the top of footing, and the program will automatically determine which wall section it is applied to. This load would typically represent the total diaphragm load going into the wall at a particular level.

All lateral loads will be applied in both left and right directions; assigning a sign to them will be meaningless. Applying the loads in each direction enables this program to provide a complete analysis of the wall system for all possible combinations of loads.

	<u>Load</u>		<u>Height</u>	
#1	8.60	k	55.000	ft
#2	7.90	k	41.250	ft
#3	5.20	k	27.500	ft
#4	4.30	k	13.750	ft
#5		k	0.000	ft
#6		k	0.000	ft
#7		k	0.000	ft
#8		k	0.000	ft
#9		k	0.000	ft

Vertical Loads Tab

	General	Lateral Loads	Vertical Loads	ACI Factors	Footing																																																																																				
			<table border="1"> <thead> <tr> <th></th> <th>Dead</th> <th>Live</th> <th>Short Term</th> </tr> </thead> <tbody> <tr> <td>#1</td> <td>11.50 k</td> <td></td> <td>10.10 k</td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>55.000 ft</td> <td>Hz Dist. = 14.000 ft</td> </tr> <tr> <td>#2</td> <td>11.50 k</td> <td></td> <td>10.10 k</td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>41.250 ft</td> <td>Hz Dist. = 13.750 ft</td> </tr> <tr> <td>#3</td> <td>11.50 k</td> <td></td> <td>10.10 k</td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>27.500 ft</td> <td>Hz Dist. = 13.750 ft</td> </tr> <tr> <td>#4</td> <td>11.50 k</td> <td></td> <td>10.10 k</td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>14.000 ft</td> <td>Hz Dist. = 13.750 ft</td> </tr> <tr> <td>#5</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>0.000 ft</td> <td>Hz Dist. = 0.000 ft</td> </tr> <tr> <td>#6</td> <td>21.60 k</td> <td>13.90 k</td> <td></td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>55.000 ft</td> <td>Hz Dist. = 8.000 ft</td> </tr> <tr> <td>#7</td> <td>21.60 k</td> <td>13.90 k</td> <td></td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>41.250 ft</td> <td>Hz Dist. = 6.000 ft</td> </tr> <tr> <td>#8</td> <td>21.60 k</td> <td>13.90 k</td> <td></td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>27.500 ft</td> <td>Hz Dist. = 3.000 ft</td> </tr> <tr> <td>#9</td> <td>21.60 k</td> <td>13.90 k</td> <td></td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>13.750 ft</td> <td>Hz Dist. = 3.250 ft</td> </tr> <tr> <td>#10</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td>Vert. Dist. =</td> <td>0.000 ft</td> <td>Hz Dist. = 0.000 ft</td> </tr> </tbody> </table>		Dead	Live	Short Term	#1	11.50 k		10.10 k		Vert. Dist. =	55.000 ft	Hz Dist. = 14.000 ft	#2	11.50 k		10.10 k		Vert. Dist. =	41.250 ft	Hz Dist. = 13.750 ft	#3	11.50 k		10.10 k		Vert. Dist. =	27.500 ft	Hz Dist. = 13.750 ft	#4	11.50 k		10.10 k		Vert. Dist. =	14.000 ft	Hz Dist. = 13.750 ft	#5					Vert. Dist. =	0.000 ft	Hz Dist. = 0.000 ft	#6	21.60 k	13.90 k			Vert. Dist. =	55.000 ft	Hz Dist. = 8.000 ft	#7	21.60 k	13.90 k			Vert. Dist. =	41.250 ft	Hz Dist. = 6.000 ft	#8	21.60 k	13.90 k			Vert. Dist. =	27.500 ft	Hz Dist. = 3.000 ft	#9	21.60 k	13.90 k			Vert. Dist. =	13.750 ft	Hz Dist. = 3.250 ft	#10					Vert. Dist. =	0.000 ft	Hz Dist. = 0.000 ft		
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Loads

Enter the unfactored vertical point loads applied to the wall. These loads represent gravity loads being supported by the wall at various heights. The load may have dead, live, and short term components.

Load Location

This location is in reference to the lower left edge of the bottom wall section. By entering the coordinates of the load from this position, the program will automatically determine which wall section the load is applied to. These vertical loads are used in all calculations.

ACI Factors Tab

This tab specifies the load factors to be used by the program when calculation the factored dead, live, and short term loads to be used in the internal load combinations for determining M_u and V_u .

General	Lateral Loads	Vertical Loads	ACI Factors	Footing
Load Factors (Nomenclature per ACI 318-02 Appx C)				
ACI C-1 && C-2	Dead Load		<input style="width: 80px;" type="text" value="1.400"/>	
ACI C-1 && C-2	Live Load		<input style="width: 80px;" type="text" value="1.700"/>	
ACI C-1 && C-2	Short Term		<input style="width: 80px;" type="text" value="1.700"/>	
....seismic = ST * :			<input style="width: 80px;" type="text" value="1.100"/>	(for C-1, C-2, and C-3)
ACI C-2	Group Factor		<input style="width: 80px;" type="text" value="0.750"/>	
ACI C-3	Dead Load Factor		<input style="width: 80px;" type="text" value="0.900"/>	
ACI C-3	Short Term Factor		<input style="width: 80px;" type="text" value="1.300"/>	
1994 UBC 1921.2.7 Seismic Zone 3 & 4 factors				
"1.4"	Factor		<input style="width: 80px;" type="text" value="1.400"/>	
"0.9"	Factor		<input style="width: 80px;" type="text" value="0.900"/>	

Footing Tab

General	Lateral Loads	Vertical Loads	ACI Factors	Footing
Allowable Soil Pressure			<input style="width: 80px;" type="text" value="5,000.0"/>	psf
Distance @ Left			<input style="width: 80px;" type="text" value="8.000"/>	ft
Wall Length			14.000	ft
Distance @ Right			<input style="width: 80px;" type="text" value="8.000"/>	ft
Footing Length			30.000	ft
Width			<input style="width: 80px;" type="text" value="6.000"/>	ft
Thickness			<input style="width: 80px;" type="text" value="48.00"/>	in
fc			<input style="width: 80px;" type="text" value="3,000.0"/>	psi
Fy			<input style="width: 80px;" type="text" value="60,000.0"/>	psi
Rebar Cover			<input style="width: 80px;" type="text" value="3.500"/>	in
Minimum Steel Reinf. Percentage			<input style="width: 80px;" type="text" value="0.0014"/>	
Kern Width			5.000	ft

Allowable Soil Pressure

Enter the maximum allowable soil bearing pressure that can be sustained by the soil.

Distance @ Left

Enter the distance the footing extends past the left end of the bottom most shear wall section.

Wall Length

This value is repeated from the "General" tab so that you know the proportions of footing length.

Distance @ Right

Enter the distance the footing extends past the left end of the bottom most shear wall section.

Footing Length

This value is calculated as the two "distance" projections plus wall length.

Footing Width

Enter the footing width to be used in the analysis. This width may be modified at any time for optimizing design.

Footing Thickness

Enter the footing thickness to be used in the analysis. This thickness may be modified at any time for optimizing design.

f'c

Enter the concrete compressive strength to be used in the footing calculation.

Fy

Enter the steel yield stress for the reinforcing to be used in the footing analysis.

Rebar Cover

Enter the cover over tension reinforcing which will be placed in the bottom of the footing. This distance will be subtracted from footing thickness to obtain the d to be used in calculating RU for the footing and for one-way shear calculations.

Kern Width

The kern distance is equal to footing length divided by 6. The "kern" region is the area in the center of the footing where the resultant of upward soil pressure can be and still maintain full pressure under the entire footing. This area extend Length/6 on either side of the center of the footing.

If the resultant lies outside this area the footing will be under partial compression and the soil pressure diagram will be triangular.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Wall Results Tab

Wall	Footing	Soil, Stability	Sketch	Printing		
Wall Analysis....		<u>Bottom</u>	<u>2nd Level</u>	<u>3rd Level</u>	<u>4th Level</u>	<u>5th Level</u>
Vs : Story Shear . . .		34.37	28.28	20.89	11.79	1.74 k
Ms w/ Lat Right . . .		2,026.4	1,157.0	653.8	75.8	8.7 k-ft
Ms w/ Lat Left		-1,179.6	-781.6	-341.5	-151.6	-8.7 k-ft
Uplift @ Left End . . .		0.00	0.00	0.00	0.00	0.00 k
Uplift @ Right End . .		0.00	0.00	0.00	0.00	-23.05 k
Vu = Vs * Factor(s)		70.377	52.634	36.143	18.942	2.436 k
vu : Applied		43.64	50.77	58.83	986.56	126.87 psi
vc * .85		69.7	70.7	81.6	93.3	156.6 psi
vn: max=.6*10*sqrt(fc)		328.634	328.6	328.6	328.6	328.6 psi
Horizontal As Req'd . .		0.36	0.36	0.24	1.43	0.24 in2
Vertical As Req'd		0.36	0.36	0.24	1.43	0.24 in2
Nu : Axial		433.02	344.24	203.36	102.95	8.12 k
Mu : Actual		2,729.1	1,577.2	872.7	263.5	12.2 k-ft
Bending As Req'd		5.38	4.26	2.66	999.00	999.00 in2
Footing Analysis....						
Max. Service Soil Pressure						4,591.75 psf
Max. Footing Shear						58.57 psi
Allowable						93.11 psi
Max. Bending Moment						1,166.17 k-ft
Required Steel Area						7.92 in2
Min. Overturning Stability Ratio						3.21 :1

Vs : Story Shear

This value is the summation of the lateral forces applied at and above the Analysis Height for a particular section.

Ms : Story OTM

This value is the summation of the overturning moments induced from loads applied above the Analysis Height. Included are applied lateral loads, Wall Section Weight * ZIKCS, and applied vertical loads that are not at the center of the wall.

Uplift

This value first calculates the moments created by the applied lateral loads, vertical loads, wall weight, and lateral wall weight overturning the wall about the base. If overturning stability is not satisfied, the net moment is divided by (Wall Length -1'-0") to obtain this number. Depending on the actual placement of tension reinforcing, multiply this force by Actual d/Wall Length to arrive at an adjusted force.

The lateral loads you have entered are combined with the calculated lateral wall weight loads and applied in both directions to get the maximum uplift at either end. Since the program allows general placement of vertical loads and offset walls, an analysis of both directions must be performed.

Vu = Vs * Factor(s)

This is equal to the Vs:Story Shear times the Load Factor specified in the loading table plus the lateral wall weight times 1.05 or 1.275 for seismic or wind cases.

Shear Analysis**Vu :**

Applied To determine the actual factored unit shear at the wall section, Vu is divided by wall thickness and d.

Vc * .85

Calculated using UBC equations 11-32 and 11-33 (if applicable). These formulas consider the effect of axial load on shear stress.

Nu : Axial

This value is used in determining the allowable unit shear stress. Vertical loads and wall weight above the Analysis Height are combined with load factors to arrive at this axial load.

Mu: Moment

All lateral and vertical loads above the Analysis Height are combined with load factors to calculate the actual moment acting at the base of each wall section.

Code Min. Area %

If $\Phi * VU < VC/2$, then Horiz % = 0.002 and Vert % = 0.0012

If $\Phi * VU \geq VC/2$, then Horiz % = $\text{MIN}(0.0025, (VU - VC)/\text{area})$

Vert % per ACI 11-35, 0.0025

Shear Area Req'

This is the shear reinforcing required per foot of wall to resist the shear forces.

Bending Analysis**Ru**

The resisting modulus of the section is calculated using the wall thickness, steel depth equal to 0.8 * Wall length, and $\Phi = 0.9$.

As Req'd Each End

Area of tension reinforcement required at each end of the wall to resist bending forces.

Footing Results Tab

Wall	Footing	Soil, Stability	Sketch	Printing
Overturning Stability...				
<i>Lateral Loads Applied to Left</i>				
	Overturning Moment		1,804.04	k-ft
	Resisting Moment		6,628.87	k-ft
	Stability Ratio		3.674	: 1
<i>Lateral Loads Applied to Right</i>				
	Overturning Moment		1,804.04	k-ft
	Resisting Moment		5,782.06	k-ft
	Stability Ratio		3.205	: 1
One-Way Shear Check...				
	vu @ Left End of Footing		47.825	psi
	vu @ Right End of Footing		58.571	psi
	vn * phi : Allowable		93.113	psi
Bending Design...				
<i>@ Left End of Footing</i>				
	Mu		956.83	k-ft
	Ru		89.48	psi
	As % Req'd		0.0020	in2
	As Req'd		6.471	in2
<i>@ Right End of Footing</i>				
	Mu		1,166.17	k-ft
	Ru		109.06	psi
	As % Req'd		0.0025	in2
	As Req'd		7.918	in2

Overturning Stability

Overall stability is calculated by including the footing weight with moments due to vertical and lateral loads about each end of the base of the footing. For load applied to the left, moments are taken about the left edge of the footing and vice versa.

One-Way Shear Check

For both of the following shear checks, V_c :Allow is calculated using : $V_c = 2 * f'c^{1/2} * .85$

Bending Design

Min. As

Enter the minimum allowable steel percentage you wish the program to use when finding the area of steel required.

Mu : Moment

The maximum moment acting on the footing due to factored soil pressures is calculated at the edge of the wall. The moment due to footing weight is subtracted from the soil pressure moment to determine this actual maximum moment.

Ru

Resisting modulus due to applied moment.

% As Required

The required steel percentage is calculated by first finding the required steel area due to bending moments:

$$\% \text{ Req'd} = (1/m) * (1 - [1 - (2*m*Ru)/Fy]^{1/2})^{1/2}$$

If this area is greater than $200/F_y$ then it is compared to your Min AS % value and the larger used. If it is less than $200/F_y$, it is multiplied by 1.33 and again compared to $200/F_y$. The minimum of those two values is then compared to your Min AS % value and the larger used

As:Required

This is equal to the As% value calculated previously multiplied by the width and d distances of the footing.

Soil & Stability Tab

Wall	Footing	Soil, Stability	Sketch	Printing
Soil Pressures		<u>Service</u>	<u>ACI Eq. C-1</u>	
Static Soil Pressure @ Left		1,909.23 psf	2,801.50 psf	
Static Soil Pressure @ Right		2,238.52 psf	3,190.69 psf	
			<u>ACI Eq. C-2 & C-3</u>	
<i>Soil Pressures w/ Short Term Load Applied To Left</i>				
@ Left Side of Footing		3,607.92 psf	5,365.31 psf	
@ Right Side of Footing		539.83 psf	1,069.99 psf	
<i>Soil Pressures w/ Short Term Load Applied To Right</i>				
@ Left Side of Footing		0.00 psf	0.00 psf	
@ Right Side of Footing		4,591.75 psf	6,692.45 psf	
Wall & Footing Stability...				
		<u>Service Loads</u>	<u>ACI C-1</u>	<u>ACI C-2 & C-3</u>
Total Vertical Loads		373.30	539.30	579.18k
<i>Overturing Moments...</i>				
No Lat. or S.T. Loads		148.18	175.13 k-ft	
Lat & ST Loads to Left		1,380.64	1,932.89k-ft	
Lat & ST Loads to Right		2,227.44	3,118.42k-ft	
<i>Resultant Ecc. From Centerline...</i>				
No Lat. or S.T. Loads		0.397	0.325 ft	
Lat & ST Loads to Left		-3.698	-3.337ft	
Lat & ST Loads to Right		5.967	5.384ft	

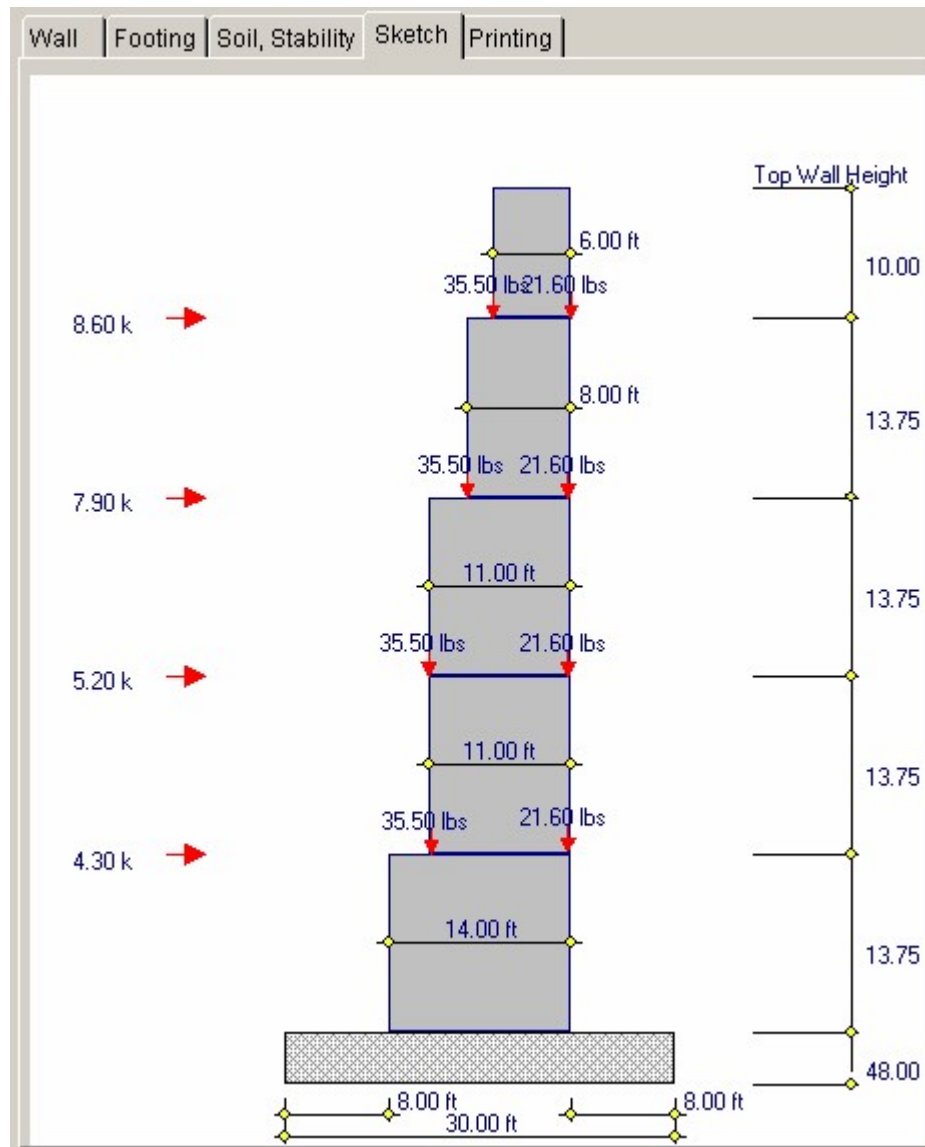
Wall/Footing Stability

This section provides a table of information on the overall stability and pressure resultants for the wall/footing system. To determine the maximum conditions, three lateral load analyses are performed; no lateral load at all, lateral load applied to the left, and lateral load applied to the right. This satisfies all load combinations as far as direction of forces is concerned.

For each of these force directions, ACI load factor combinations 9-1, 9-2, and 9-3 are evaluated. This results in a set of eccentricities for all possible conditions which will be used to determine factored soil pressures for footing design.

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Wall | Footing | Soil, Stability | Sketch | Printing

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Applied Loads	<input checked="" type="checkbox"/>
Wall Data	<input checked="" type="checkbox"/>
Wall Analysis	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Footing Dimensions	<input checked="" type="checkbox"/>
Wall & Footing Stability	<input checked="" type="checkbox"/>
Overall Wall & Footing Stability	<input checked="" type="checkbox"/>
Soil Pressures	<input checked="" type="checkbox"/>
ACI Factors	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 11:04PM, 26 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 000000
 User: KW0000001, Ver 5.8.0, 10-Sep-2003
 (c)1983-2003 ENERCALC Engineering Software

Concrete Shear Wall Design

Page 1

c:\ec55\examples.acw Concrete Calc

Description 4 Story Wall with setbacks

General Information

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Total Wall Height	55.000 ft	Seismic Factor	0.3000
Concrete Weight	145.000 pcf	Seismic Zone	4
Live & Short Term Load Combined		Min Wall As% for Bending	0.0014
		Overburden Weight	0.00 psf

Applied Loads

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design.
 Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2.

Short Term Lateral Loads...

Vertical Loads...

	Load	Height		Dead	Live	Short Term	Vertical	Horz.
#1	8.600 k	55.000 ft	#1	11.500		10.100 k	55.000	14.000 ft
#2	7.900 k	41.250 ft	#2	11.500		10.100 k	41.250	14.000 ft
#3	5.200 k	27.500 ft	#3	11.500		10.100 k	27.500	14.000 ft
#4	4.300 k	13.750 ft	#4	11.500		10.100 k	13.750	14.000 ft
#6	k	ft	#6	21.600	13.900	k	55.000	8.000 ft
#7	k	ft	#7	21.600	13.900	k	41.250	6.000 ft
#8	k	ft	#8	21.600	13.900	k	27.500	6.000 ft
#9	k	ft	#9	21.600	13.900	k	13.750	6.000 ft
#10	k	ft	#10	21.600	13.900	k	13.750	ft

Wall Data

	Bottom	2nd Level	3rd Level	4th Level
Analysis Height	0.00 ft	13.750 ft	27.500 ft	41.250 ft
Wall Offset (datum) ft		5.000 ft	6.000 ft	8.000 ft
Wall Length	14.000 ft	9.000 ft	8.000 ft	6.000 ft
Wall Thickness	12.000 in	12.000 in	8.000 in	8.000 in
f'c: Concrete	3,000.0 psi	3,000.0 psi	3,000.0 psi	3,000.0 psi
Fy: Rebar	60,000.0 psi	60,000.0 psi	60,000.0 psi	60,000.0 psi
Effective Depth	11.200 ft	7.200 ft	6.400 ft	4.800 ft

Wall Analysis

	Bottom	2nd Level	3rd Level	4th Level
Vs: Story Shear	34.37 k	27.08 k	19.69 k	10.99 k
M _s w/ Lat Right	1,660.8 k-ft	787.8 k-ft	352.3 k-ft	-25.3 k-ft
M _s w/ Lat Left	-1,128.0 k-ft	-869.3 k-ft	-480.5 k-ft	-176.4 k-ft
Uplift @ Left End	k	k	k	k
Uplift @ Right	k	k	k	k
Vu = Vs * Factor(s)	63.475 k	45.732 k	30.915 k	15.389 k
Vu: Applied	39.36 psi	44.11 psi	50.32 psi	33.40 psi
Nu: Axial	459.71 k	290.99 k	185.93 k	91.10 k
Mu: Moment	2,414.37 k-ft	1,174.17 k-ft	639.24 k-ft	246.96 k-ft
vc ^{0.85}	71.671 psi	68.892 psi	75.593 psi	67.062 psi
vn: max = 10 * sqrt(f'c) * .6	328.63 psi	328.63 psi	328.63 psi	328.63 psi

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Rev: 580000 User: K794000001 Ver 5.8.6, 10-Sep-2003 (c)1983-2003 ENERCALC Engineering Software **Concrete Shear Wall Design** Page 2
 e:\acdf\example\acac\Concrete Calc

Description 4 Story Wall with setbacks

Summary				
	<u>Bottom</u>	<u>2nd Level</u>	<u>3rd Level</u>	<u>4th Level</u>
Vu	63.48 k	45.73 k	30.92 k	15.39 k
Horizontal As Req'd	0.36 in2	0.36 in2	0.24 in2	0.19 in2
Vertical As Req'd	0.36 in2	0.36 in2	0.24 in2	0.12 in2
Mu : Actual	2,414.37 k-ft	1,174.17 k-ft	639.24 k-ft	246.96 k-ft
Bending As Req'd	5.38 in2	3.46 in2	2.05 in2	1.30 in2

Footing			
f_c	3,000.0 psi	Footing Dimensions	
F_y	60,000.0 psi	Dist. Left	6.000 ft
Rebar Cover	3.500 in	Wall Length	14.000 ft
Footing Thickness	32.00 in	Dist. Right	6.000 ft
Width	6.000 ft	Total Ftg Length	26.000 ft
		Kern Width	4.333 ft

Wall & Footing Stability...			
	<u>Service Loads</u>	<u>ACI Eq. C-1</u>	<u>ACI Eq. C-2 & C-3</u>
Total Vertical Loads	348.28 k	508.45 k	544.16 k
Overturning Moments...			
No Lateral or Short Term Loads	111.16 k-ft	118.09 k-ft	
Lat & ST Loads Applied to Left	1,121.34 k-ft		1,569.87 k-ft
Lat & ST Loads Applied to Right	1,909.26 k-ft		2,672.96 k-ft
Resultant Ecc. From Centerline...			
No Lateral or Short Term Loads	0.319 ft	0.232 ft	
Lat & ST Loads Applied to Left	-3.220 ft		-2.885 ft
Lat & ST Loads Applied to Right	5.482 ft		4.912 ft

Overall Wall & Footing Stability			
	<u>Overturning Moment</u>	<u>Resisting Moment</u>	<u>Stability Ratio</u>
Overturning Stability			
Lateral Loads Applied to Left	1,383.71 k-ft	5,446.86 k-ft	3.936 : 1
Lateral Loads Applied to Right	1,383.71 k-ft	4,658.94 k-ft	3.367 : 1
One-Way Shear Check			
@ Left End of Footing	68.419 psi	Allowable	93.113 psi
@ Right End of Footing	86.257 psi		
Bending Design	<u>Mu</u>	<u>Ru</u>	<u>As % Req'd</u> <u>As Req'd</u>
@ Left End of Footing	588.95 k-ft	134.27 psi	0.0031 6.277 in2
@ Right End of Footing	740.82 k-ft	168.90 psi	0.0033 6.840 in2
Min. As % =	0.0014		

Soil Pressures			
	<u>Service</u>	<u>ACI Eq. C-1</u>	
Soil Pressures			
Static Soil Pressure @ Left	2,068.16	3,084.59 psf	
Static Soil Pressure @ Right	2,397.03	3,433.98 psf	
Soil Pressures w/ Short Term Load Applied To Left		<u>Service</u>	<u>ACI Eq. C-2 & C-3</u>
@ Left Side of Footing		3,891.38 psf	5,810.49 psf
@ Right Side of Footing		573.81 psf	1,165.90 psf
Soil Pressures w/ Short Term Load Applied To Right		<u>Service</u>	<u>ACI Eq. C-2 & C-3</u>
@ Left Side of Footing		0.00 psf	0.00 psf
@ Right Side of Footing		5,147.34 psf	7,475.61 psf

2.7 Square Footing

This program provides design analysis for square footings subjected to axial load only. If you wish to design a rectangular footing subjected to axial loads and overturning

moments about one or both axis, the "General Footing" program is required.

Each footing may have a dead, live, and short term axial load applied, have soil overburden weight included, and you may choose to omit live load during short term load combinations.

Allowable soil pressure and a short-term allowable increase factor is used to check soil pressures, and the program also allows you to specify allowable soil pressure increases based on footing size and placement depth.

The program calculates actual soil pressure for static and short-term loadings, one and two-way shears, and calculates required reinforcement using the factored soil pressures.

Number of Bars Required				Total As Req'd =
15: #4's	7: #6's	4: #8's	3: #10's	2.946 in2
10: #5's	5: #7's	3: #9's		

Basic Usage

- Dead, Live, and Short-Term loads are entered as loads applied to the footing (no horizontal shear or overturning moments are allowed with this program). Entering the Seismic Zone will instruct the program how to factor the short-term loads. Entering 0" will signal that short-term loads are wind loads, and 1" through 4" indicates zones. Overburden Weight will be applied as a dead load (for example assuming soil, concrete, or other static material), and you can specify to Include Live Load with short-term loads (typically combined for wind but ignored for

seismic).

- Footing Width, Thickness, and Material Strengths will be used to evaluate footing weight, pressures and shears. If Rebar Size and Quantity are entered, the program will calculate the moment capacity of the footing, otherwise it will provide design analysis and reinforcing requirements.
- Soil Data is entered to define the allowable soil bearing pressure for static (DL+LL) and short-term (DL+LL+ST) load combinations. By entering the footing depth and Allowable Increases, you can simply modify footing dimensions and have the allowable pressures automatically modified.

Unique Features

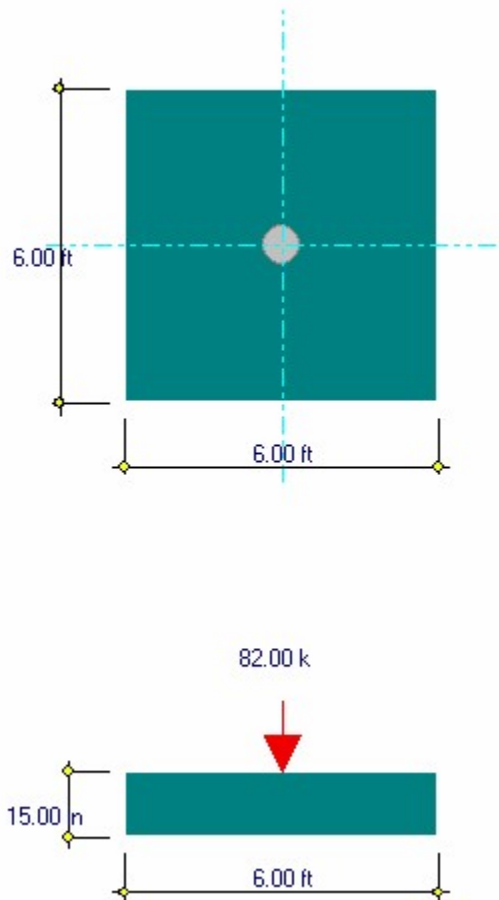
- Up to six footings can be designed at one time on one program calcsheet, allowing fast design of dozens of footings.
- The program can both analyze and design steel reinforcing
- Allowable soil pressure increases based on depth of embedment and width can be automatically calculated whenever footing dimensions change.
- Program checks both beam and punching shear.

Assumptions & Limitations

- Only a square footing can be designed using this program.
- One and two-way shear and moments are calculated using the equivalent column dimension.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General	Loadings	Depth & Width Increases	ACI Factors
Description Simple Footing Design			
Footing SQUARE Dimension	6.000	ft	
Thickness	15.00	in	
# of Bars	7		
Bar Size	6		
Rebar Cover	3.250	in	
Column Dimension	8.000	in	
Allowable Soil Bearing	2,500.0	psf	
fc	2,000.0	psi	
Fy	40,000.0	psi	
Concrete Weight	145.00	pcf	
Load Duration Factor	1.330		
Seismic Zone	4		
Min Allow % Reinf	0.0014		

Footing Square Dimension

Since only square footings can be designed, the length and width must be identical.

Thickness

Total footing thickness.

Bars

You can enter the size and number of bars in your footing for analysis of a footing, or allow the program to calculate this for you (see Reinforcing). If you specify the reinforcing, the program will automatically determine the bending capacity.

Bar Size

Bar Size #3 thru #18 bars are allowed.

Rebar Cover

Distance from the bottom of the footing to the centerline of the reinforcing.

Column Dimension

Enter an equivalent column square dimension to be used for calculation of moments and shears.

Allowable Soil Bearing

Enter the allowable soil pressure for static loadings.

f'_c

Concrete compressive strength.

F_y

Yield stress of reinforcing steel.

Concrete Weight

By entering a non-zero number here, the weight of the footing will be included in soil bearing pressure calculations. Enter this number in PCF.

Load Duration Factor

This factor will be applied to the Basic Allowable Soil Pressure to calculate allowable pressure under short-term loads.

Seismic Zone

This entry is used to control overall ACI load factoring. When wind loads generate the short-term forces, enter a 0" here. When seismic loads generate the short-term loads, enter 1" through 4" here to indicate the UBC seismic zone. When zone 3 or 4 is used, the special load factoring provisions of the UBC are applied.

Min Allow % Reinf.

Loadings Tab

General	Loadings	Depth & Width Increases	ACI Factors
Loading...			
Dead Load	<input type="text" value="34.00"/>	<input type="text"/>	k
Live Load	<input type="text" value="36.00"/>	<input type="text"/>	k
Short Term Load	<input type="text" value="12.00"/>	<input type="text"/>	k
Overburden Weight	<input type="text" value="110.00"/>	<input type="text"/>	psf
Combine LL w/ ST?	<input type="checkbox"/>		

Loads

Each footing can support a dead, live, and short-term load. The load is applied to the center of the footing (no eccentricities are allowed).

Overburden Weight

This represents an applied uniform dead load over the footing. It can be from soil, concrete slab, or storage loads.

Combine LL & ST?

This entry instructs the program when to include live load with short-term loads. Typically, wind load analysis will include live load, while short-term loads due to seismic forces are not combined with live loads.

Depth & Width Increases Tab

General	Loadings	Depth & Width Increases	ACI Factors
Increases Based on Depth			
Ftg. Base Depth below Surface		<input type="text" value="0.000"/>	ft
Increase per foot of depth		<input type="text"/>	psf
when footing is below		<input type="text" value="0.000"/>	ft
Increase per foot of width		<input type="text"/>	psf
when footing is wider than		<input type="text" value="0.000"/>	ft

Footing Base Depth Below Surface

Enter the depth of the bottom of the footing below the adjacent soil. This item will only need be entered if you wish to use the Depth Increase capability.

Increase per foot of Depth

These two values define how the soil pressure will be increased when increases based on depth are used. When Below defines the minimum depth of the footing below the soil for the increase to take effect. Per Foot Depth is the allowable pressure increase per foot of additional embedment greater than the minimum value.

Increase per foot of width

These values define how the soil pressure will be increased when increases based on footing width are used. When Wider defines the minimum footing width of the footing for the increase to take effect. Per Foot Width is the allowable pressure increase per foot of additional width beyond the minimum value.

ACI Factors

This tab specifies the load factors to be used by the program when calculation the factored dead, live, and short term loads to be used in the internal load combinations for determining μ & ν .

General	Loadings	Depth & Width Increases	ACI Factors
Load Factors (Nomenclature per ACI 318-02 Appx C)			
ACI C-1 && C-2 Dead Load			1.400
ACI C-1 && C-2 Live Load			1.700
ACI C-1 && C-2 Short Term			1.700
....seismic = ST * :			1.100
ACI C-2 Group Factor			0.750
ACI C-3 Dead Load Factor			0.900
ACI C-3 Short Term Factor			1.300
Add'l Seismic "1.4" Factor			1.400
Add'l Seismic "0.9" Factor			0.900

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Summary Tab

Summary		Sketch	
Footing OK			
Soil Pressures...			
Max. Static Soil Pressure		2,235.69 psf	
Allow Static Soil Pressure		2,500.00 psf	
Max. Short Term Soil Pressure		1,569.03 psf	
Allow Short Term Soil Pressure		3,325.00 psf	
Shear Stresses..			
Actual 1-Way Shear		43.19 psi	
Allowable 1-Way Shear		76.03 psi	
Actual 2-Way Shear		129.93 psi	
Allowable 2-Way Shear		152.05 psi	
Bending Analysis...			
Mu : Actual		12.20 k-ft / ft	
Mn * Phi : Capacity		16.74 k-ft / ft	
Rebar Requirement			
Actual Rebar "d" depth used		11.375 in	
200/Fy		0.0050	
As Req'd by Analysis		0.0027 %	
Min. Reinf % Required		0.0036 %	
Required Reinforcing		2.946 in ²	
As to USE per foot of Width		0.491 in ²	
Number of Bars Required			
Total As Req'd =		2.946 in ²	
15 : #4's	7 : #6's	4 : #8's	3 : #10's
10 : #5's	5 : #7's	3 : #9's	

Max. Static Soil Press

This is the soil pressure due to dead, live, and overburden loads, and should not exceed the Allowable Static pressure.

Allow Static Press

This soil pressure is equal to the Basic Allowable soil pressure when depth and width increases are not used. When you have specified depth or width increases, and the footing is either wider or deeper enough for them to be used, this value will reflect those additions.

Max. Short Press.

This is the soil pressure due to dead, short term, overburden loads, and optional live loads. This pressure should not exceed the Allowable Short pressure.

Allow Short Press.

This is equal to Allowable Static Pressure described above multiplied by the Short Term Factor.

One Way Shear

This is the maximum one-way shear due to factored loads for both static and short-term conditions. The shear is calculated at a distance $d + \text{Col. Dim}/2$ " away from the footing centerline.

Two Way Shear

This is the maximum two-way (punching) shear due to factored loads for both static and short-term conditions. The shear is calculated at a distance $d/2 + \text{Col. Dim}/2$ " away from the footing centerline.

Mn

This is the allowable bending capacity of the footing using the reinforcement optionally specified earlier. If the reinforcing was not entered, you can review the reinforcement calculations below for minimum requirements.

Mu/Phi

This is the maximum actual moment in the footing due to static or short-term load combinations.

Reinforcing

The required steel percentage is calculated by first finding the required steel area due to bending moments: $\% \text{ Req'd} = (1/m) * (1 - [1 - (2 * m * R_u) / F_y]^{1/2})^{1/2}$

If this area is greater than $200/F_y$ then it is compared to your Min AS % value and the maximum used.

If it is less than $200/F_y$, it is multiplied by 1.33 and again compared to $200/F_y$. The minimum of those two values is then compared to your Min AS % value and the larger used

Total As Required

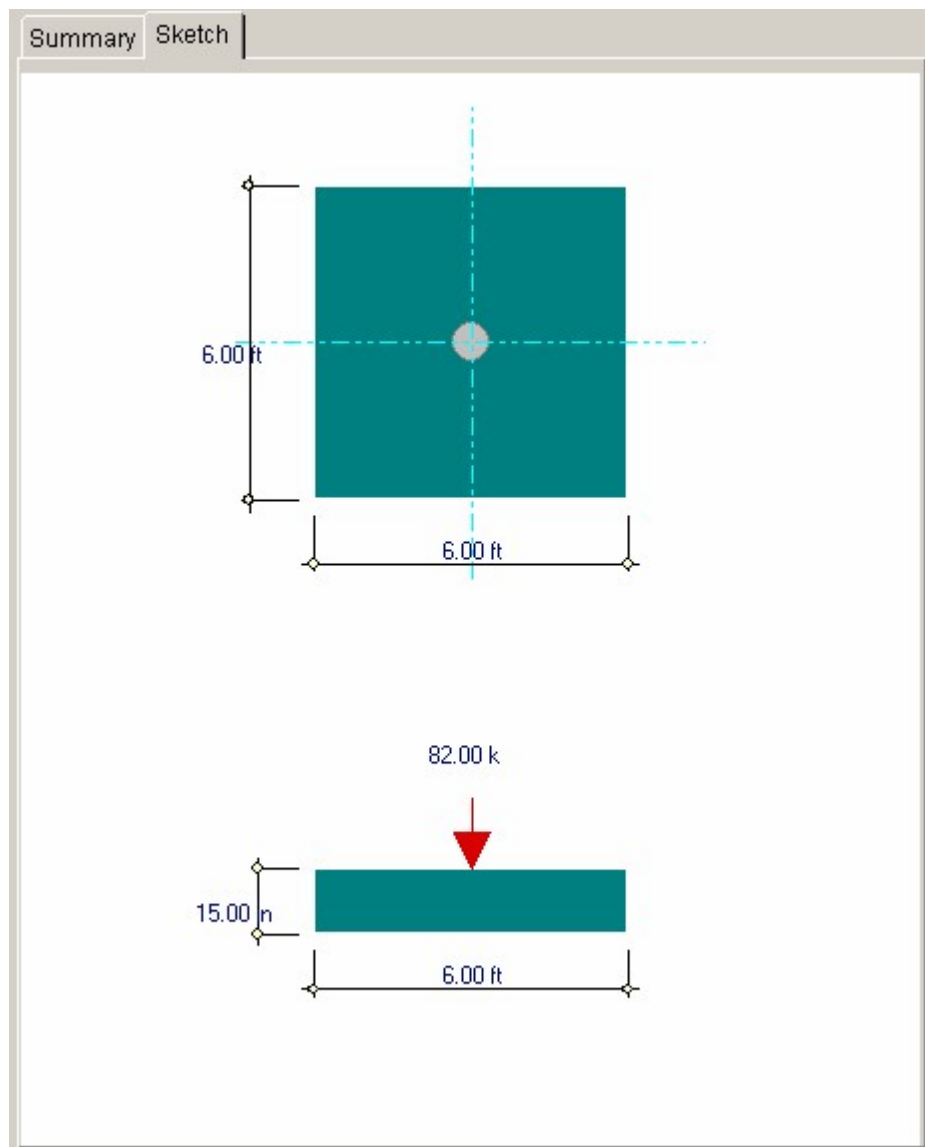
This is equal to the $A_s\%$ value calculated previously multiplied by the width and d distances of the footing.

Rebar Choices

This section lists the reinforcing choices that will supply the required area.

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title : ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 11:10PM, 26 OCT 03
 Description : Collection of example problems
 Scope : All programs in the Structural Engineering Library

Rev: 080000
 User: K/W-000001, Ver 5.8.0, 10-Sep-2003
 (c) 1983-2003 ENERCALC Engineering Software

Square Footing Design

Page 1

c:\examples\concrete\Calc

Description Simple Footing Design

General Information

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA5000

Dead Load	34,000 k	Footing Dimension	6.000 ft
Live Load	36,000 k	Thickness	15.00 in
Short Term Load	12,000 k	# of Bars	7
Seismic Zone	4	Bar Size	6
Overburden Weight	110,000 psf	Rebar Cover	3.250
Concrete Weight	145.00 pcf	f _c	2,000.0 psi
LL & ST Act Separately		F _y	40,000.0 psi
Load Duration Factor	1.330	Allowable Soil Bearing	2,500.00 psf
Column Dimension	8.00 in		

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design.
 Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

Reinforcing

Rebar Requirement

Actual Rebar 'd' depth used	11.375 in	As to USE per foot of Width	0.491 in ²
200F _y	0.0050	Total As Req'd	2.946 in ²
As Req'd by Analysis	0.0027 in ²	Min Allow % Reinf	0.0014
Min. Reinf % to Req'd	0.0036 %		

Summary

Footing OK

6.00ft square x 15.0in thick with 7- #6 bars			
Max. Static Soil Pressure	2,235.69 psf	V _u : Actual One-Way	43.19 psi
Allow Static Soil Pressure	2,500.00 psf	V _n *Phi : Allow One-Way	76.03 psi
Max. Short Term Soil Pressure	1,569.03 psf	V _u : Actual Two-Way	129.93 psi
Allow Short Term Soil Pressure	3,325.00 psf	V _n *Phi : Allow Two-Way	152.05 psi
Mu : Actual	12.20 k-ft / ft	Alternate Rebar Selections...	
Mn * Phi : Capacity	16.74 k-ft / ft	15 #4's	10 #5's
		5 #7's	4 #8's
		3 #9's	3 #10's

2.8 General Footing

This program provides a complete and detailed analysis of rectangular footings subjected to axial, horizontal shear and moment loads about one or both axes. The program can also handle:

- Biaxial bending analysis, moments, shears, and eccentric loads can all be combined simultaneously to calculate maximum soil pressures at the footing corners.

- The column can be specified to be off-center from the footing centerline, resulting in calculated soil pressures, shears, and moments being taken at the offset column's perimeter.
- Overburden dead load to account for loads surcharging the footing.
- Lateral loads applied along one or both axes to produce overturning moments due to their eccentricity above the bottom of the footing.
- Dead, live, and short-term moments applied about one or both axis.
- Specification of seismic zone to indicate whether wind loads, or seismic loads are being used, and if the special load factoring provisions of the UBC should be used for seismic zones 3 and 4.

A column pedestal and equivalent column dimensions can be entered to identify location of shear transfer to footing and dimensions used to calculate beam and punching shear stresses.

The user can select whether the analysis should be performed by applying lateral and moments separately about both axes, or if a full biaxial soil pressure/shear/moment analysis is required. When a biaxial analysis is performed, skew bending theory is correlated with Esling's equations to generate a neutral axis and soil pressure matrix at 2,500 points under the footing. This pressure grid is then used to calculate maximum shears and moments.

Final calculations give results for ACI load factor combination equations 9-1, 9-2, and 9-3 simultaneously. One way shears, two-way shears, bending moments, reinforcing requirements at all four sides, and overturning stability ratios about both axes are given.

ENERCALC c:\ECS\EXAMPLES.ECIV - General Footing Design

General Footing Design

Tools & Settings | ? Help | Design | Print | Cancel | Save

General | Loads | ACI Factors | Summary | Sketch | Printing

Description: Load Offset, M & V Along both axes

Allowable Soil Bearing: 4,500.00 psf
 Short Term Increase: 1.330
 Seismic Zone: 0
 Biaxial Analysis:
 Combine LL w/ ST?:

Concrete Weight: 145.00 pcf
 fc: 3,000.0 psi
 Fy: 60,000.0 psi
 Min Steel %: 0.0014
 Rebar Center To Edge Dist.: 3.500 in

Dimensions...
 Width along X-X Axis: 6.750 ft
 Length along Y-Y Axis: 10.170 ft
 Footing Thickness: 36.00 in
 Col Dim. Along X-X Axis: 12.000 in
 Col Dim. Along Y-Y Axis: 24.000 in
 Base Pedestal Height: 12.000 in

Footing Design OK

Soil Pressures

	Dead + Live	Dead + Live + Short Term
Max Soil Pressure	2,575.2 psf	2,735.6 psf
Allowable	4,500.0 psf	5,985.0 psf
"X" Ecc. of Resultant	0.0 in	5.0 in
"Y" Ecc. of Resultant	0.0 in	2.7 in

Moments per ft

	Max. Moment	Ru	As Req'd
Mu @ Left	12.69 k-ft	13.3 psi	0.55 in ² /ft
Mu @ Right	12.69 k-ft	13.3 psi	0.55 in ² /ft
Mu @ Top	25.61 k-ft	26.9 psi	0.55 in ² /ft
Mu @ Bottom	25.61 k-ft	26.9 psi	0.55 in ² /ft

Footing Shears

	Maximum	Allowable: Vn * Phi
Vu : 1-Way	11,586 psi	93,113 psi
Vu : 2-Way	23,803 psi	186,226 psi

Overtuning Stability

	Dead + Live	DL+LL+ST
X-X Axis Stability Ratios	999,000 : 1	22,994 : 1
Y-Y Axis Stability Ratios	999,000 : 1	8,016 : 1
Allowable Ratio =		1,500 : 1

Service Load Soil Pressures

	Left	Right	Top	Bottom
DL+LL	2,575.23	2,575.23	2,575.23	2,575.23 psf
DL+LL+ST	1,246.54	2,735.63	2,250.63	1,731.54 psf

Factored Load Soil Pressures

	Left	Right	Top	Bottom
ACI Eq. C-1	3,833.00	3,833.00	3,833.00	3,833.00 psf
ACI Eq. C-2	1,330.71	2,920.35	2,402.60	1,848.46 psf
ACI Eq. C-3	1,163.28	2,652.91	2,100.30	1,615.69 psf

Basic Usage

- Soil Pressure and Increase Factor specify the allowable soil bearing pressure to compare with analysis values. Base Pedestal Height defines the height at which all shears will be applied. Seismic Zone sets the ACI load factoring for equation 9-2 and 9-3. Overburden Weight is considered to be a dead load applied to the top of the footing (but excluding the column area). You can set the Biaxial Analysis flag to indicate whether or not the complex biaxial analysis procedures should be used, applying all lateral loads and moments to the footing at once.
- Axial Loads are allowed to be applied by dead, live, or short term (but must be a positive + sign). The short-term load will be factored based on the Seismic Zone. Using the X Ecc. and Y Ecc. entries, you can shift the axial load application point off the column centerline, applying an additional moment to the footing.
- Footing Dimensions can be entered, along with the equivalent column dimensions, which will be used to calculate one and two way shear stresses.
- Y-Y and X-X Axis Forces allow you to apply service (unfactored) shears and moments to the footing. Dead, live, and short-term components are allowed, and the values can be either negative or positive.
- It is CRITICAL that you establish an X-Y coordinate system before entering footing dimensions, applied shears and moments, and axial load eccentricities. We have used this convention:
 - Top = +Y Bottom = -Y Right = +X Left = -X

- Calculating the program will determine the actual service and factored soil pressures, moments and shears, and required reinforcing. You can then modify footing sizes to obtain optimum designs.

Unique Features

- User can apply moments and shears about two axes and have maximum and minimum soil pressures, one way shears, and bending moments evaluated for each side of the footing.
- Axial load can be applied eccentrically from the footing centerline.
- Full biaxial analysis combination of shears and moments about each axis is provided.
- Footing size can be easily varied to optimize design.
- Overburden and footing weight are taken into consideration.
- Short-term load can be specified as either seismic or wind.
- One way shear is calculated based on maximum condition for each of the four sides.
- Bending moment and required reinforcing are calculated based on the maximum condition for each of the four sides in accordance with Ultimate Strength Design Methods.

Assumptions & Limitations

- Sliding restraint on footing not checked.
- Design method follows Ultimate Strength Design.
- Biaxial analysis uses "Skew Bending Theories" correlated with Sling's equations for pressures in bodies where tension is not allowed. From the neutral axis position and maximum soil pressure calculated, a 2,500 cell pressure grid is created under the footing. The pressures within various areas are then added to calculate one way shears, two-way shears, and bending moments.
- This program assumes there will be a net upward force on the footing.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.

Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General		Loads		ACI Factors	
Description					
Load Offset, M & V Along both axes					
Allowable Soil Bearing	4,500.00	psf			
Short Term Increase	1.330				
Seismic Zone	0				
Biaxial Analysis	<input type="checkbox"/>				
Combine LL w/ ST ?	<input type="checkbox"/>				
Concrete Weight	145.00	pcf			
fc	3,000.0	psi			
Fy	60,000.0	psi			
Min Steel %	0.0014				
Rebar Center To Edge Dist.	3.500	in			
Dimensions...					
Width along X-X Axis	6.750	ft			
Length along Y-Y Axis	10.170	ft			
Footing Thickness	36.00	in			
Col Dim. Along X-X Axis	12.000	in			
Col Dim. Along Y-Y Axis	24.000	in			
Base Pedestal Height	12.000	in			

Allowable Soil Pressure

Enter the maximum allowable soil bearing pressure for static (not short term) loading.

Short Term Increase

If a short term increase in soil pressure will be allowed, enter the multiplier here.

Seismic Zone

This entry is used to control overall ACI load factoring. When wind loads generate the short-term forces, enter a 0" here. When seismic loads generate the short-term loads, enter 1" through 4" here to indicate the UBC seismic zone. When zone 3 or 4 is used, the special load factoring provisions of the UBC section 2625 are applied.

Biaxial Analysis

This YES/NO flag instructs the program whether or not to combine all loads and moments simultaneously about each axis when performing the analysis. If you answer NO, the moments and shears about each axis are applied separately to produce maximum soil bearing pressures.

Combine LL & ST

This entry instructs the program when to include live load with short-term loads. Typically, wind load analysis will include live load, while short-term loads due to seismic forces are usually not combined with live loads.

Concrete Weight

By entering a non-zero number here, the weight of the footing will be included in soil bearing pressure, shear, and bending calculations.

 f_c

Allowable compressive stress for the concrete.

 F_y

Allowable yield stress of the reinforcing steel

Rebar CL to Soil

Enter the distance from the bottom of the footing to the centerline of the reinforcing. This will be subtracted from the footing thickness to calculate rebar d distance when determining required reinforcing and shear depths/distances.

Minimum Steel %

Enter the minimum percentage of steel reinforcing that you wish to use when determining required reinforcing area. See As Required for a discussion of how this item is used.

Loads Tab

General	Loads	ACI Factors
Applied Vertical Load...		
Dead Load	<input type="text" value="87.200"/>	k
Live Load	<input type="text" value="52.100"/>	k
Short Term Load	<input type="text" value="12.000"/>	k
...ecc along X-X Axis	<input type="text" value="0.000"/>	in
...ecc along Y-Y Axis	<input type="text" value="0.000"/>	in
Overburden Wt.		
	<input type="text" value="110.000"/>	psf
Applied Moments...		
	Rotation on Y-Y Axis (pressures @ left & right)	Rotation on X-X Axis (pressures @ top & bot)
Dead Load	<input type="text"/>	<input type="text"/>
Live Load	<input type="text"/>	<input type="text"/>
Short Term	<input type="text" value="21.50"/>	<input type="text" value="6.20"/>
Applied Shears...		
	Rotation on Y-Y Axis (pressures @ left & right)	Rotation on X-X Axis (pressures @ top & bot)
Dead Load	<input type="text"/>	<input type="text"/>
Live Load	<input type="text"/>	<input type="text"/>
Short Term	<input type="text" value="9.00"/>	<input type="text" value="6.00"/>

Axial Loads

You can apply a dead, live, and short-term axial load to the footing. These loads will be DL+LL and DL+ST+[LL] combinations when calculating maximum bearing pressures.

Eccentricity

This eccentricity specifies the distance the column is shifted from the center of the footing. These eccentricities will cause the axial loads to induce moments onto the footing.

Overburden Weight

This represents an applied uniform surcharge load over the footing. It can be from soil, concrete slab, or storage loads.

Moments

This program allows you to apply dead, live, and short-term moments at the footing centerline. Positive moments will cause higher soil pressures at the top and right side of the footing. This corresponds to the +Y and +X directions.

Shear

You can also apply horizontal dead, live, and short-term shears at the plane of the top of the footing. To calculate the actual overturning moments due to these loads, the shears are multiplied by the Footing Thickness + Base Height. Positive shears will cause higher soil pressures at the top and right side of the footing. This corresponds to the +Y and +X directions.

ACI Factors Tab

This tab specifies the load factors to be used by the program when calculation the factored dead, live, and short term loads to be used in the internal load combinations for determining μ_u & V_u .

General Loads ACI Factors	
Load Factors (Nomenclature per ACI 318-02 Appx C)	
ACI C-1 && C-2 Dead Load	1.40
ACI C-1 && C-2 Live Load	1.70
ACI C-1 && C-2 Short Term	1.70
....seismic = ST * :	1.10 used in C-1, C-2, and C-3
ACI C-2 Group Factor	0.75
ACI C-3 Dead Load Factor	0.90
ACI C-3 Short Term Factor	1.30
Additional Seismic Zone 3 & 4	
"1.4" Factor	1.40
"0.9" Factor	0.90

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Summary Tab

This section summarizes the results of the analysis. For each loading direction, the maximum service and factored soil pressures are given for both static and short term loading. Notice that for service load bearing pressure, only DL+LL and DL+[LL]+ST are used as load combinations. For factored load pressures, ACI equations C-1, C-2, and C-3 are used. When a biaxial analysis is used, the pressures at left, right, top, and bottom reflect all loads applied at once. For non-biaxial analysis, the loads are applied about each axis separately to give separate maximum Left/Right and Top/Bottom pressures.

Summary		Sketch	Printing
Footing Design OK			
Soil Pressures		<u>Dead + Live</u>	<u>Dead + Live + Short Term</u>
Max Soil Pressure		2,575.2 psf	2,735.6 psf
Allowable		4,500.0 psf	5,985.0 psf
"X" Ecc. of Resultant		0.0 in	5.0 in
"Y" Ecc. of Resultant		0.0 in	2.7 in
Moments per ft	<u>Max. Moment</u>	<u>Ru</u>	<u>As Req'd</u>
Mu @ Left	12.69 k-ft	13.3 psi	0.55 in ² /ft
Mu @ Right	12.69 k-ft	13.3 psi	0.55 in ² /ft
Mu @ Top	25.61 k-ft	26.9 psi	0.55 in ² /ft
Mu @ Bottom	25.61 k-ft	26.9 psi	0.55 in ² /ft
Footing Shears	<u>Maximum</u>	<u>Allowable : Vn * Phi</u>	
Vu : 1-Way	11.586 psi	93.113 psi	
Vu : 2-Way	23.803 psi	186.226 psi	
Overturning Stability	<u>Dead + Live</u>	<u>DL+LL+ST</u>	
X-X Axis Stability Ratios	999.000 :1	22.994 :1	
Y-Y Axis Stability Ratios	999.000 :1	8.016 :1	
	Allowable Ratio =	1.500 :1	
Service Load Soil Pressures			
	<u>Left</u>	<u>Right</u>	<u>Top</u> <u>Bottom</u>
DL+LL	2,575.23	2,575.23	2,575.23 2,575.23 psf
DL+LL+ST	1,246.54	2,735.63	2,250.63 1,731.54 psf
Factored Load Soil Pressures			
	<u>Left</u>	<u>Right</u>	<u>Top</u> <u>Bottom</u>
ACI Eq. C-1	3,833.00	3,833.00	3,833.00 3,833.00 psf
ACI Eq. C-2	1,330.71	2,920.35	2,402.60 1,848.46 psf
ACI Eq. C-3	1,163.28	2,552.91	2,100.30 1,615.89 psf

Max. & Allow Pressure

This is the absolute maximum service load soil pressure for both load conditions as presented in the area titled Service Load Pressure within the summary box.

X Ecc. & Y Ecc.

These eccentricities are the location of the total vertical force resultant considering axial load eccentricity, and applied moments and lateral shears. This eccentricity is measured from the footing centerline.

Mu

Maximum factored moments created about all four sides of the footing from factored soil pressures generated by ACI equation 9-1, 9-2, and 9-3.

Vu: 1 Way

By using the Column Dimension values to determine the shear plane for one-way bending, this is the maximum shear by checking all four sides of the footing and all three ACI equations.

Vu:2 Way

By using the Column Dimension values to determine the punching shear perimeter area, this is the maximum punching from checking all three ACI equations.

Overturing Stability

Factor of safety against overturning by applying the loads and moments about each axis. Biaxial analysis has no effect on this number. 999" indicates there is no overturning.

Service Load Pressures

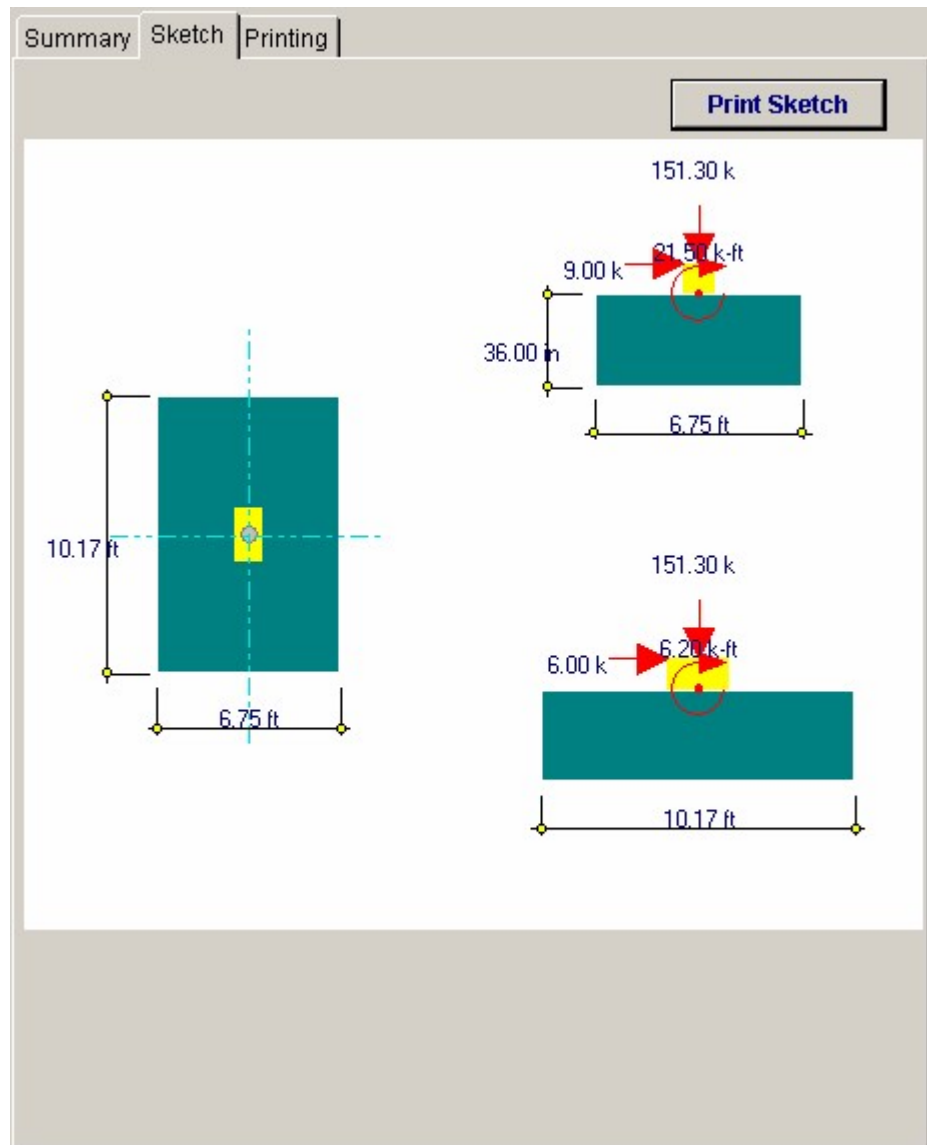
This table shows the actual service load soil pressures at all four sides of the footing due to static and short-term load combinations.

Factored Load Pressure

This table shows the actual factored load soil pressures at all four sides of the footing by combining all loads into ACI load combinations 9-1,9-2, and 9-3.

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Summary | Sketch | Printing

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Loads	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Footing Design	<input checked="" type="checkbox"/>
Soil Pressure Summary	<input checked="" type="checkbox"/>
ACI Factors	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 11:14PM, 26 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 500000
 User: N740800001, Ver 5.8.0, 10-Sep-2003
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General Footing Analysis & Design

Page 1

c:\eef\examples\enr Concrete Calc

Description Load Offset, M & V Along both axes

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

General Information		Dimensions...	
Allowable Soil Bearing	4,500.0 psf	Width along X-X Axis	6.750 ft
Short Term Increase	1.330	Length along Y-Y Axis	10.170 ft
Seismic Zone	0	Footing Thickness	36.00 in
Live & Short NOT Combined		Col Dim. Along X-X Axis	12.00 in
fc	3,000.0 psi	Col Dim. Along Y-Y Axis	24.00 in
Fy	60,000.0 psi	Base Pedestal Height	12.000 in
Concrete Weight	145.00 pcf	Min Steel %	0.0014
Overburden Weight	110.00 psf	Rebar Center To Edge Distance	3.50 in

Loads

Applied Vertical Load...

Dead Load	87.200 k	...ecc along X-X Axis	0.000 in
Live Load	52.100 k	...ecc along Y-Y Axis	0.000 in
Short Term Load	12.000 k		

Applied Moments...

	Creates Rotation about Y-Y Axis (pressures @ left & right)	Creates Rotation about X-X Axis (pressures @ top & bot)
Dead Load	k-ft	k-ft
Live Load	k-ft	k-ft
Short Term	21.500 k-ft	6.200 k-ft

Applied Shears...

	Creates Rotation about Y-Y Axis (pressures @ left & right)	Creates Rotation about X-X Axis (pressures @ top & bot)
Dead Load	k	k
Live Load	k	k
Short Term	9.000 k	6.000 k

Summary

Footing Design OK

6.75ft x 10.17ft Footing, 36.0in Thick, w/ Column Support 12.00 x 24.00in x 12.0in high

	DL+LL	DL+LL+ST	Actual	Allowable
Max Soil Pressure	2,575.2	2,735.6 psf	25.613 k-ft per ft	
Allowable	4,500.0	5,985.0 psf	Required Steel Area	0.546 in ² per ft
X Ecc. of Resultant	0.000 in	5.048 in	Shear Stresses...	$V_u \cdot \Phi$
Y Ecc. of Resultant	0.000 in	2.651 in	1-Way	93.113 psi
X-X Min. Stability Ratio	22.994	1.500 :1	2-Way	186.226 psi
Y-Y Min. Stability Ratio	8.016			

Footing Design

Shear Forces	ACI C-1	ACI C-2	ACI C-3	$V_n \cdot \Phi$	
Two-Way Shear	23.80 psi	12.04 psi	10.60 psi	186.23 psi	
One-Way Shears...					
V _u @ Left	1.25 psi	0.96 psi	0.84 psi	93.11 psi	
V _u @ Right	1.25 psi	0.30 psi	0.27 psi	93.11 psi	
V _u @ Top	11.59 psi	6.80 psi	5.98 psi	93.11 psi	
V _u @ Bottom	11.59 psi	4.99 psi	4.40 psi	93.11 psi	
Moments	ACI C-1	ACI C-2	ACI C-3	R_u / Φ	As Req'd
Mu @ Left	12.69 k-ft	4.01 k-ft	3.55 k-ft	13.3 psi	0.55 in ² per ft
Mu @ Right	12.69 k-ft	8.83 k-ft	7.76 k-ft	13.3 psi	0.55 in ² per ft
Mu @ Top	25.61 k-ft	14.69 k-ft	12.92 k-ft	26.9 psi	0.55 in ² per ft
Mu @ Bottom	25.61 k-ft	11.23 k-ft	9.89 k-ft	26.9 psi	0.55 in ² per ft

ENERCALC Engineering Software
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 Corona del Mar, CA 92660
 Voice: 949-645-0151
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Title : ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 11:14PM, 26 OCT 03
 Description : Collection of example problems
 Scope : All programs in the Structural Engineering Library

Rev: 580000 User: RYV-0600001, Ver 5.8.0, 10-Sep-2003 (c)1983-2003 ENERCALC Engineering Software **General Footing Analysis & Design** Page 2
 c:\e055\exam ples.ecw\Concrete Calc

Description Load Offset, M & V Along both axes

Soil Pressure Summary

Service Load Soil Pressures	Left	Right	Top	Bottom
DL + LL	2,575.23	2,575.23	2,575.23	2,575.23 psf
DL + LL + ST	1,248.54	2,735.63	2,250.63	1,731.54 psf
Factored Load Soil Pressures				
ACI Eq. C-1	3,833.00	3,833.00	3,833.00	3,833.00 psf
ACI Eq. C-2	1,330.71	2,920.35	2,402.60	1,848.46 psf
ACI Eq. C-3	1,183.28	2,552.91	2,100.30	1,615.89 psf

ACI Factors (per ACI 318-02, applied internally to entered loads)

ACI C-1 & C-2 DL	1.400	ACI C-2 Group Factor	0.750	Add'l '1.4' Factor for Seismic	1.400
ACI C-1 & C-2 LL	1.700	ACI C-3 Dead Load Factor	0.900	Add'l '0.9' Factor for Seismic	0.900
ACI C-1 & C-2 ST	1.700	ACI C-3 Short Term Factor	1.300		
.....seismic = ST * :	1.100				

2.9 Combined Footing

This program provides design and analysis of rectangular footings supporting two columns applying axial load, lateral shear, and bending moment forces. The program is ideal for footings supporting braced frames (short-term uplift at one end) and for eccentrically loaded footings which need to have semi-uniform soil loading patterns.

Each column can apply dead, live, and short term loads to the footing, can have their own depth and width dimensions, and can be located at any distance apart and from the footing ends. The columns must lie on the footing centerline along the longer axis .

In addition to the column loads, footing weight and overburden loads are added. A typical feature allows you to specify a seismic zone number from 0" through 4", 0" indicating wind loads and 1" through 4" being used by the program to control seismic load factoring.

Footing projections on either side of the columns, footing width, and footing thickness can be easily modified to design a footing to satisfy soil pressure, shear, bending, and overturning stability requirements.

The program provides complete analysis and design results by combining all loads using factored ACI load combinations 9-1, 9-2, and 9-3, including one way shears, two way shears, service and factored soil pressures, and bending moments and reinforcing.

Soil Pressure @	Actual	Allowable
Left End		
Static DL + LL	839.85 psf	2,500.00 psf
Short DL + LL + ST	633.06 psf	3,325.00 psf
Right End		
Static DL + LL	793.62 psf	2,500.00 psf
Static DL + LL + ST	755.51 psf	3,325.00 psf

@	Soil Pressure	Eccentricity
Left End		
ACI Eq. C-1 Comb.	1,221.43 psf	0.116 ft
ACI Eq. C-3	886.23 psf	0.360 ft
ACI Eq. C-3	693.39 psf	
Right End		
ACI Eq. C-1 Comb.	1,154.20 psf	-0.116 ft
ACI Eq. C-2	1,067.71 psf	0.360 ft
ACI Eq. C-3	693.84 psf	

Basic Usage

- Allowable Soil Pressure and Short Term Factor specify the maximum soil bearing pressure allowed for static (DL+LL) and short term (DL+LL+ST) load combinations. Seismic Zone should be set to 0" if short-term loads are due to wind, and 1" through 4" if seismic. If you wish to Combine Live Loads with short term loads, all short term calculations will use DL+LL+ST (typical seismic design uses DL+ ST only).
- Concrete Weight and Overburden will be added in as dead loads during the analysis. (Overburden will be applied to the area above the footing, less the area specified for

column size). Minimum A_s % will be used as an absolute minimum when determining reinforcing requirements.

- Axial loads, lateral shears, and moments with dead, live, and short-term components can be applied to each column. Although these loads act along the footing centerline, they can be positive or negative, allowing design of footings supporting braced frames.
- Sign Conventions are as follows:
 - Positive Axial Loads act downward.
 - Positive Lateral Shears act to the right, creating greater soil pressure at the right side of the footing.
 - Positive Moments act clockwise, creating greater soil pressure at the right side of the footing.
- Footing Dimensions can be specified for the distance left of column #1, right of column #2, and the distance between columns. These are added to give the total footing length. Footing width, thickness, and rebar clear cover complete the specifying of footing dimensions.
- Calculating the program will determine the actual service and factored soil pressures, moments and shears, and required reinforcing. You can then modify footing sizes and reinforcing to obtain optimum designs. All three ACI load factor combinations 9-1, 9-2, and 9-3 are evaluated simultaneously.

Unique Features

- This program easily sizes a footing supporting two loads with moments and lateral shears, and gives maximum and minimum soil pressures, one and two way shears and bending moments evaluated for both ends of the footing.
- Accepts both static and seismic/wind loads, and evaluates soil pressure for both.
- Footing size can be easily varied to optimize design.
- Overburden and footing weight are taken into consideration.
- Short-term load can be specified as either seismic or wind.
- User may specify whether or not live loads act during short term.
- Distance between columns is divided into 250 increments for calculation of maximum moments.

Assumptions & Limitations

- Both columns must lie on the footing centerline along one axis.
- Beam on Elastic Foundation effects of soil are not considered. This analysis assumes that soil pressures will be linear under a rigid footing.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.

Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on

the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General		Design Data...	Loads	ACI Factors
Description		Simple combined footing w/short term loads		
Allow Soil Pressure		2,500.0		psf
Footing Size...				
Distance Left		4.500		ft
Between Columns		17.000		ft
Distance Right		3.000		ft
Footing Length		24.50		
Width		8.000		ft
Thickness		24.00		in
Column Support Pedestal Sizes...				
#1 : Square Dimension		16.000		in
...Height		16.000		in
#2 : Square Dimension		21.000		in
...Height		6.000		in

Allowable Soil Pressure

Enter the maximum allowable soil bearing pressure for static loading.

Distance Left

This is the distance the footing extends on the left side of the footing. It is measured from the centerline of the left side column to the edge of footing.

Between Columns

This is the separation between columns, measured between the column centerline's.

Distance Right

This is the distance the footing extends on the right side of the footing. It is measured from the centerline of the right side column to the edge of footing.

Footing Length

The total length of the footing which equals Distance Left + Between Columns + Distance Right.

Width

Width of the footing

Thickness

Thickness of the footing

Column Support Pedestal Sizes

These dimensions define the distances that will be used to compute moments and shears. The edge of this area defines an assumed solid column at which moments will act. Distances of d and $d/2$ will be added to the edge location for calculation of shear forces. Overburden weight is not applied to this area.

Design Data Tab

The screenshot shows the 'Design Data...' tab selected. The 'Design Data...' section contains the following fields:

- Seismic Zone: 4
- Include LL w/ ST:
- Short Term Increase: 1.330

The 'Concrete Data...' section contains the following fields:

- f'_c : 3,000.0 psi
- F_y : 60,000.0 psi
- Min As Pct: 0.0014
- Distance to CL of Rebar: 3.500 in
- Concrete Wt: 140.00 pcf

Seismic Zone

This entry is used to control overall ACI load factoring. When wind loads generate the short-term forces, enter a 0" here. When seismic loads generate the short-term loads, enter 1" through 4" here to indicate the UBC seismic zone. When zone 3 or 4 is used, the special load factoring provisions of the UBC are applied.

Include Live Load w/ Short Term Loads

This entry instructs the program when to include live load with short-term loads. Typically, wind load analysis will include live load, while short-term loads due to seismic forces are not combined with live loads.

Short Term Increase

If a short-term increase in soil pressure will be allowed, enter the multiplier here.

f'c

Allowable compressive stress for the concrete.

Fy

Allowable yield stress of the reinforcing steel.

Min. As %

Enter the minimum percentage of steel reinforcing that you wish the program to use when determining required reinforcing area.

Distance to Centerline of Rebar

Enter the distance from the top or bottom of the footing to the centerline of the reinforcing. This will be subtracted from the footing thickness to calculate rebar d distances when determining required reinforcing and shear depths and distances.

Concrete Weight

By entering a non-zero number here, the weight of the footing will be included in soil bearing pressure calculations.

Loads Tab

	@ Left Column	@ Right Column
Vertical Loads...		
Dead Load	21.000 k	16.000 k
Live Load	16.000 k	13.000 k
Short Term Load		5.000 k
Applied Moments...		
Dead Load		
Live Load		
Short Term Load		
Applied Shears...		
Dead Load		
Live Load		
Short Term Load	3.000 k	3.000 k
Overburden		200.000 psf

Vertical Loads

The footing may support two columns transferring axial, shear, and moment loads to the footing. Each of these columns must lie along the centerline of the footing, but may be positioned at any location along the footings length. Axial Each axial load can have dead, live, and short term components.

Applied Moments

Each column may apply a moment to the footing, consisting of dead, live, and short-term components. Positive moments will apply a Clockwise torque to the footing (opposite the typical direction for right-hand-rule). Positive moments will increase the soil pressure at the right end of the footing.

Applied Shears

Each column may apply a lateral shear at the top of the footing, consisting of dead, live, and short-term components. Positive shears will apply a force to the right. Positive shears will be applied at a vertical eccentricity equal to the Footing Thickness and the resulting moment will increase the soil pressure at the right end of the footing.

Overburden

This is a general load that you may input to apply an additional uniform area load on the top of the entire footing. This load is also applied where the column dimensions are defined and so will be slightly conservative.

ACI Factors Tab

This tab specifies the load factors to be used by the program when calculation the factored dead, live, and short term loads to be used in the internal load combinations for determining M_u & V_u .

General	Design Data...	Loads	ACI Factors
Load Factors (Nomenclature per ACI 318-02 Appx C)			
ACI C-1 & C-2 for Dead Load		<input type="text" value="1.400"/>	
ACI C-1 & C-2 for Live Load		<input type="text" value="1.700"/>	
ACI C-1 & C-2 for Short Term		<input type="text" value="1.700"/>	
... seismic = ST * :		<input type="text" value="1.100"/>	(C-1, C-2, and C-1)
ACI C-2 Group Factor		<input type="text" value="0.750"/>	
ACI C-3 Dead Load Factor		<input type="text" value="0.900"/>	
ACI C-3 Short Term Factor		<input type="text" value="1.300"/>	
Additional Factors for Seismic Zone 3 & 4			
"1.4" Factor		<input type="text" value="1.400"/>	
"0.9" Factor		<input type="text" value="0.900"/>	

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection

diagram.

Results Tab

This tab gives the calculated governing values of maximum soil pressure, footing shear, and the minimum overturning stability ration for the footing considering all applied loads and load combinations.

Results	Soil Pressures	M & V Summary	Reinforcing
Footing Design OK			
Max Soil Pressure			839.85 psf
Allowable			2,500.00 psf
Vu : Max Shear			17.08 psi
Vn * Phi : Allowable			186.23 psi
Min. Overturning Stability			93.513 :1
Steel Req'd @ Left			0.34 in ² /ft
Steel Req'd @ Center			0.34 in ² /ft
Steel Req'd @ Right			0.34 in ² /ft

Overturning Stability

The overturning stability ratio for the footing is calculated considering all applied moments, shears, vertical loads, footing weight, and soil weight for both static and short-term cases.

For this value, both sides of the footing are used as a reference point for calculation of overturning ratios and the smaller value is displayed, representing the minimum factor of safety. "999" indicates there is no overturning on the footing, or the ratio is so great as to be meaningless.

As Req'd

Required area of steel is calculated by:

- Using the maximum Mu to determine the required steel percentage
- Comparing the required steel percentage with 200/Fy. If required is greater than 200/Fy, then

required is used. If the required percentage is less than $200/F_y$, the required is multiplied by 1.33 and that result compared with $200/F_y$, and the lesser value used.

The resulting percentage calculated above is compared with Minimum Steel % the user entered, and the maximum of those values multiplied by the footing area to determine required area. If $A_s = 999$, required steel exceeds $0.75 * \text{Rho Balanced}$.

Results / Soil Pressure Tab

Results	Soil Pressures	M & V Summary	Reinforcing
Unfactored Soil Pressures...			
Soil Pressure @ Left End		<u>Actual</u>	<u>Allowable</u>
Static DL + LL		839.85 psf	2,500.00 psf
Short DL + LL + ST		633.06 psf	3,325.00 psf
Soil Pressure @ Right End			
Static DL + LL		793.62 psf	2,500.00 psf
Static DL + LL + ST		755.51 psf	3,325.00 psf
ACI Factored Soil Pressures...			
@ Left End		<u>Soil Pressure</u>	<u>Eccentricity</u>
ACI Eq. C-1 Comb.		1,221.43 psf	0.116 ft
ACI Eq. C-3 "		886.29 psf	0.360 ft
ACI Eq. C-3 "		581.39 psf	
@ Right End			
ACI Eq. C-1 Comb.		1,154.20 psf	-0.116 ft
ACI Eq. C-2 "		1,057.71 psf	0.360 ft
ACI Eq. C-3 "		693.84 psf	

Static Soil Pressures

For each end of the footing, the axial loads, shears, moments, overburden, and footing weight are applied to calculate the static soil pressures. Dead and live load forces are included in this calculation, no short term loads. These pressure values are compared to the basic allowable soil bearing pressure.

Short Term Soil Pressures

This is similar to the "Static" calculation, except short term load is always included, and live load is included only if Combine LL & ST is set to YES.

Unfactored Soil Pressures

Service level soil pressures are the resulting soil pressures BEFORE any ACI load factors are applied, and are used to determine compliance with allowable soil bearing pressures. Allowable pressure for "Static" conditions is a simple restatement of the Allowable Soil Pressure entered at the top of the program. Short term allowable pressure equal the static allowable multiplied by the "Short Term Factor".

ACI Factored Soil Pressures

For both the left and right end of the footing, ACI equations 9-1, 9-2, and 9-3 are used to factor the various combinations of dead, live, and short term loads to arrive at the factored soil pressures

presented here. These pressures are used to calculate moments and shears in the footing, both at each end and between supports.

Results / M & V Summary Tab

Results	Soil Pressures	M & V Summary	Reinforcing
....Note: All moments are per unit width of footing....			
Moments...			
	ACI C-1	ACI C-2	ACI C-3
Mu @ Col #1	4.01	1.64	1.14 k-ft
Mu Btwn Cols	-14.73	-8.87	-6.08 k-ft
Mu @ Col #2	1.09	0.88	0.60 k-ft
One Way Shears...			
Vn * Phi : Allow	93.11	93.11	93.11 psi
Vu @ Col #1	4.72	1.92	1.33 psi
Vu Btwn Cols	11.51	6.93	4.50 psi
Vu @ Col #2	0.82	0.65	0.44 psi
Two Way Shears...			
Vn * Phi : Allow	186.23	186.23	186.23 psi
Vu @ Col #1	17.08	8.90	6.38 psi
Vu @ Col #2	11.10	7.11	5.26 psi

Moments

Mu for ACI Equation The bending moments for both static and short-term cases are listed here. Evaluation of bending moments include factored soil pressure (and its variation in intensity under the footing, even in cases where the eccentricity lies outside the kern), footing weight, and overburden weight. When values appear as negative, indicates that steel reinforcing must be placed in the top of the footing.

The maximum moment between columns is evaluated by finding the maximum moment at 100 points. Variation in soil pressure, footing weight, soil weight, applied moments, and moments induced by horizontal shears applied to the columns are all considered in the maximum moment calculation. For Mu at Column #1 and Column #2, the moments are induced from upward soil pressure applied to the cantilever portion of the footing, downward force from overburden and footing weight.

One-Way Shear

Using the maximum factored soil pressures presented earlier, the maximum one way shear stress at a vertical plane a distance d away from the Equivalent Column face. The vertical depth used for shear area equals footing thickness minus Rebar CL To Soil. Allowable one-way shear stress is calculated as : $2 * f'c^{1/2}$

2-Way Shear

The maximum two-way shear stress is taken on four vertical planes a distance $d/2$ away from the Equivalent Column face. The vertical depth used for shear area equals footing thickness minus Rebar CL To Soil. Allowable two-shear stress is calculated as : $4 * f'c^{1/2}$

Results / Reinforcing Tab

This tab summarizes the required reinforcing for the three important locations on the footing:

Due to moments created at the left side of the left column due to upward soil loads in the left footing projection.

Moments in the footing between the columns due to upward soil pressure.

Due to moments created at the right side of the right column due to upward soil loads in the right footing projection.

Results	Soil Pressures	M & V Summary	Reinforcing
<i>(per unit width of footing)</i>			
@ Left Edge of Col #1			
		<u>Ru/Phi</u>	<u>As Req'd</u>
	ACI Eq. C-1 Combination	10.60 psi	0.344 in ² /ft
	ACI Eq. C-2 "	4.34 psi	0.344 in ² /ft
	ACI Eq. C-3 "	3.02 psi	0.344 in ² /ft
Between Columns			
	ACI Eq. C-1 Combination	38.95 psi	0.344 in ² /ft
	ACI Eq. C-2 "	23.46 psi	0.344 in ² /ft
	ACI Eq. C-3 "	16.06 psi	0.344 in ² /ft
@ Right Edge of Col #2			
	ACI C-1 Combination	2.89 psi	0.344 in ² /ft
	ACI Eq. C-2 "	2.32 psi	0.344 in ² /ft
	ACI Eq. C-3 "	1.57 psi	0.344 in ² /ft

Ru/Phi

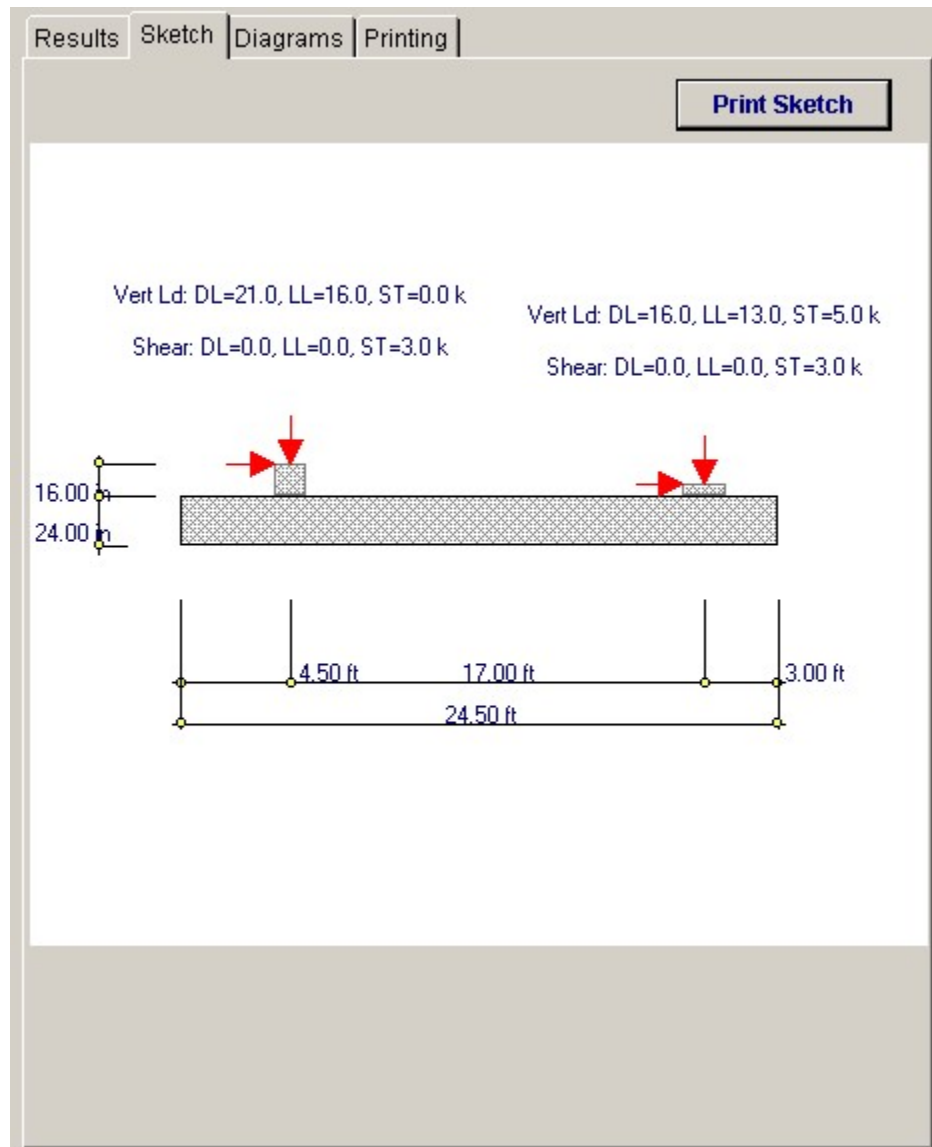
This is the resisting modulus required by the footing section which is $MU/(b * d^2 * Phi)$

As Required

This is the area of steel required per foot of footing WIDTH at the location.

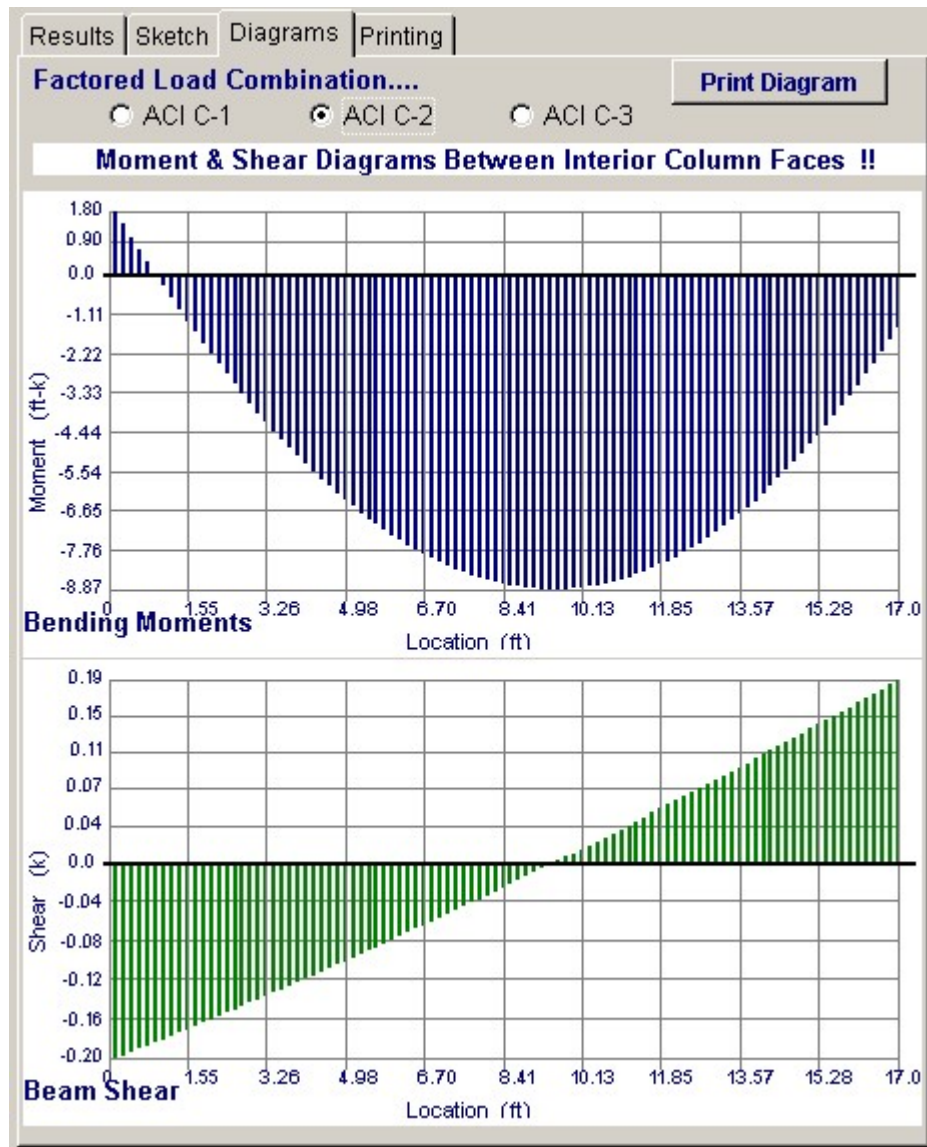
Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Diagrams Tab

This displays a moment, shear, and deflection diagram for the beam with the applied loads and end conditions. Note the two tabs...."Graphic Diagram" and "Data Table". The Data Table tab provides the entire internal analysis at the 1/500th points within the beam.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Diagrams | Printing

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Dimensions	<input checked="" type="checkbox"/>
Loads	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Soil Pressures	<input checked="" type="checkbox"/>
Moment & Shear Summary	<input checked="" type="checkbox"/>
Reinforcing	<input checked="" type="checkbox"/>
ACI Factors	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems **Job #** 97-000001
Dsgnr: MDB **Date:** 11:19PM, 26 OCT 03
Description: Collection of example problems
Scope: All programs in the Structural Engineering Library

Rev: 060000
 User: RW-0000001, Ver: 5.8.0, 10-Sep-2003
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Combined Footing Design

Page 1
 c:\enrc\examples\enrc\Concrete Calc

Description Simple combined footing w/short term loads

General Information Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA5000

Allow Soil Bearing	2,500.0 psf	f _c	3,000.0 psi
Seismic Zone	4	F _y	60,000.0 psi
Concrete Wt	140.0 pcf	Min As Pct	0.0014
Short Term Increase	1.33	Distance to CL of Rebar	3.50 in
Overburden	200.00 psf	Live & Short Term Loads Act Separately	

Dimensions

Footing Size...		Column Support Pedestal Sizes	
Distance Left	4.50 ft	#1 : Square Dimension	16.00 in
Dist. Betwn Cols	17.00 ft	...Height	16.00 in
Distance Right	3.00 ft	#2 : Square Dimension	21.00 in
Footing Length	24.50 ft	...Height	6.00 in
Width	8.00 ft		
Thickness	24.00 in		

Loads

Note: Load factoring supports 2003 IBC and 2003 NFPA 5000 by virtue of their references to ACI 318-02 for concrete design. Factoring of entered loads to ultimate loads within this program is according to ACI 318-02 C.2

Vertical Loads...	<u>@ Left Column</u>	<u>@ Right Column</u>
Dead Load	21,000 k	16,000 k
Live Load	16,000 k	13,000 k
Short Term Load	k	5,000 k
Applied Shears...		
Dead Load	k	k
Live Load	k	k
Short Term Load	3,000 k	3,000 k

Summary **Footing Design OK**

Length = 24.50ft, Width = 8.00ft, Thickness = 24.00in, Dist. Left = 4.50ft, Btwn. = 17.00ft, Dist. Right = 3.00ft

Maximum Soil Pressure	839.85 psf	Steel Req'd @ Left	0.344 in ² /ft
Allowable	2,500.00 psf	Steel Req'd @ Center	0.344 in ² /ft
Max Shear Stress	17.08 psi	Steel Req'd @ Right	0.344 in ² /ft
Allowable	186.23 psi		
Min. Overturning Stability	93.513 :1		

Soil Pressures

Soil Pressure @ Left	Actual	Allowable	ACI Factored	Eccentricity
Dead + Live	839.9	2,500.0 psf	Eq. C-1 1,221.4 psf	0.116 ft
Dead+Live+Short Term	633.1	3,325.0 psf	Eq. C-2 886.3 psf	0.360 ft
			Eq. C-3 581.4 psf	
Soil Pressure @ Right End				
Dead + Live	793.6	2,500.0 psf	Eq. C-1 1,154.2 psf	-0.116 ft
Dead+Live+Short Term	755.5	3,325.0 psf	Eq. C-2 1,057.7 psf	0.360 ft
			Eq. C-3 693.8 psf	
Stability Ratio	93.5 :1			

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Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 11:19PM, 26 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 580000
 User: KVV-0600001, Ver 5.8.0, 10-Sep-2003
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Combined Footing Design

Page 2

c:\ec55\examples.ecw\C.concrete Calcs

Description Simple combined footing w/short term loads

Moment & Shear Summary

(values for moment are given per unit width of footing)

Moments...	ACI C-1	ACI C-2	ACI C-3
Mu @ Col #1	4.01 k-ft/ft	1.64 k-ft/ft	1.14 k-ft/ft
Mu Btwn Cols	-14.73 k-ft/ft	-8.87 k-ft/ft	-6.08 k-ft/ft
Mu @ Col #2	1.09 k-ft/ft	0.88 k-ft/ft	0.60 k-ft/ft
One Way Shears...			
Vn : Allow * 0.85	93.113 psi	93.113 psi	93.113 psi
Vu @ Col #1	4.721 psi	1.915 psi	1.333 psi
Vu Btwn Cols	11.514 psi	6.927 psi	4.495 psi
Vu @ Col #2	0.818 psi	0.651 psi	0.442 psi
Two Way Shears...			
Vn : Allow * 0.85	186.226 psi	186.226 psi	186.226 psi
Vu @ Col #1	17.084 psi	8.897 psi	6.384 psi
Vu @ Col #2	11.099 psi	7.111 psi	5.258 psi

Reinforcing

(values given per unit width of footing)

	@ Left Edge of Col #1		Between Columns		@ Right Edge of Col #2	
	Ru/Phi	As Req'd	Ru/Phi	As Req'd	Ru/Phi	As Req'd
ACI C-1	10.60 psi	0.344 in ² /ft	38.95 psi	-0.344 in ² /ft	2.89 psi	0.344 in ² /ft
ACI C-2	4.34 psi	0.344 in ² /ft	23.46 psi	-0.344 in ² /ft	2.32psi	0.344 in ² /ft
ACI C-3	3.02 psi	0.344 in ² /ft	16.06 psi	-0.344 in ² /ft	1.57psi	0.344 in ² /ft

ACI Factors

(per ACI, applied internally to entered loads)

ACI C-1 & C-2 DL	1.400	ACI C-2 Group Factor	0.750	Additional Seismic "1.4" Factor	1.400
ACI C-1 & C-2 LL	1.700	ACI C-3 Dead Load Factor	0.900	Additional Seismic "0.9" Factor	0.900
ACI C-1 & C-2 ST	1.700	ACI C-3 Short Term Factor	1.300		
...seismic = ST * :	1.100				

2.10 Rebar Embedment Length

This program calculates embedment and splice lengths for deformed steel rebar in concrete. Since typical embedment lengths are readily available in tables, this program is primarily for developing tables of embedment lengths when unusual conditions effect the lengths

Two major categories of embedment calculation are available; straight embedment and hooked embedment. The program calculates the basic tension embedment length for straight and hooked cases, and compression embedment for straight cases only.

This program also lists required lap splice lengths for Class "A" and "B" splices.

ENERCALC c:\ECSS\EXAMPLES.ECW - Rebar Embedment Length Calcs

Rebar Embedment Length Calcs

Tools & Settings Help Print Cancel Save

General Bar # 1 Bar # 2 Bar # 3 Bar # 4 Bar # 5

Bar Size # 4

fc 3,000.0 psi

Fy 60,000.0 psi

Code Edition ACI 318-91 ACI 318-02, '03 IBC, '03 NFPA 5000

Rebar Area 0.200 in

Class A Splice 16.43 in

Class B Splice 21.36 in

Compression Splice 15.00 in

Straight Embedment

ACI 12.2.3.1 1

Lightweight Concrete ?

Is it a TOP Bar ?

As req'd / As actual 1.000

Within Ties/Stirrups ?

Tension Embedment...

Basic Before Adjustments 8.764 in

Final after adjustments 16.432 in

Compression Embedment...

Basic Before Adjustments 10.954 in

Final after adjustments 10.954 in

Hooked Embedment...

Adequate Cover ?

Epoxy Coating ?

Lightweight Concrete ?

Basic Before Adjustments 10.954 in

Final after adjustments 9.202 in

Basic Usage

- This program provides five columns to specify different rebar sizes and embedment conditions. The entry descriptions below apply to all columns.
- Enter Bar Data. Rebar size # (in 1/8th inch increments), f'_c , and F_y .
- Enter Modification Factors. Here you can specify whether the cover and spacing requirements of ACI 12.2.3 are satisfied, whether lightweight concrete is used, bar location, excess steel area ratio, or if the bars are enclosed in spirals. The answers to these items will be used to apply factors to the basic embedment lengths for determining the final Modified embedment lengths.
- The minimum embedment lengths are calculated for both straight and hooked conditions. If your actual construction details provide only limited embedment lengths, you can modify the various factors and recalculate until the desirable lengths are attained.

Unique Features

To reduce the infrequent task of calculating specialized rebar embedment lengths, this program brings together all the code requirements of ACI sections 12.2, 12.5, 12.16, and 12.17 in a quick, concise, and flexible calculation tool.

Assumptions & Limitations

- Rebar areas are chosen from an internally stored table of values typically used in engineering practice.
- Evaluation of embedment lengths and splices follow ACI.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.

Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General	Bar # 1	Bar # 2	Bar # 3	Bar # 4	Bar # 5
Bar Size # <input type="text" value="1"/>					
f _c <input type="text" value="3,000.0"/> psi					
F _y <input type="text" value="60,000.0"/> psi					
Code Edition	<input checked="" type="radio"/> ACI 318-91 <input type="radio"/> ACI 318-02, '03 IBC, '03 NFPA 5000				
				Rebar Area	0.200 in
				Class A Splice	16.43 in
				Class B Splice	21.36 in
				Compression Splice	15.00 in
Straight Embedment					
ACI 12.2.3.1 :	<input type="text" value="1"/>				
Lightweight Concrete ?	<input type="checkbox"/>			Tension Embedment..	
Is it a TOP Bar ?	<input type="checkbox"/>			Basic Before Adjustments	8.764 in
As req'd / As actual	<input type="text" value="1.000"/>			Final after adjustments	16.432 in
Within Ties/Stirrups ?	<input type="checkbox"/>			Compression Embedment...	
				Basic Before Adjustments	10.954 in
				Final after adjustments	10.954 in
Hooked Embedment...					
Adequate Cover ?	<input checked="" type="checkbox"/>			Basic Before Adjustments	10.954 in
Epoxy Coating ?	<input checked="" type="checkbox"/>			Final after adjustments	9.202 in
Lightweight Concrete ?	<input type="checkbox"/>				

Rebar Size

Enter the rebar size # which should be used for the analysis in each column.

f_c

Enter the 28 day concrete compressive strength in this location.

F_y

Enter the steel yield strength in this location.

Code Edition

Select between ACI 318-91 and several later code. This changes the look of the tab slightly to provide the proper items for the selected code.

Actual Rebar Area

Based upon the rebar size number entered immediately above, the typical area used in engineering practice is recalled from an internal table and shown here.

Straight Embedment**ACI 12.2.3**

Enter the appropriate multiplication factor depending on how your reinforcing satisfies ACI section 12.2.3. This section is new in the 1989 code, and represents how rebar cover, spacing, and placement effect the required embedment lengths. These provisions are primarily aimed at limiting dangerous crack propagation to the concrete surface.

Lightweight Concrete

Enter 1.33" for lightweight concrete or 1.18" for sand lightweight concrete as defined by the ACI. For normal weight concrete, enter 1".

Top Bar Placement

Enter 1.4" if the rebar is located so that there is more than 12" of concrete below the bar (or other condition that would necessitate a top condition).

As Required / As Actual Ratio

When the required area of steel is less than what has been provided, enter the ratio of required/supplied area here.

Within Ties / Spirals

When the reinforcement is enclosed in a spiral not less than 1/4" diameter nor more than 4 in pitch, enter 0.75".

Hooked Embedment**Adequate Cover**

Answer 1" if cover exceeds 2-1/2" normal to the plane of the hook, or 2" beyond the embedment of the 90 degree hook extension.

Lightweight Concrete

Enter 1.33" for lightweight concrete or 1.18" for sand lightweight concrete as defined by the ACI. For normal weight concrete.

Embedment Lengths**Tension**

Basic Before Adjustments : The program calculates the basic tension embedment length per ACI section 12.3.3, but not less than 12".

Final After Adjustments : This value represents the Basic Tension Embedment Length multiplied by all of the adjustment factors specified above.

Compression

Basic Before Adjustments : The program calculates the basic compression embedment length ACI section 12.3, but not less than 8".

Final After Adjustments : This value represents the Basic Compression Embedment Length multiplied by all of the adjustment factors specified above.

Hooked

Basic Before Adjustments : The program calculates the basic tension embedment length per ACI section 12.3.3, but not less than 12".

Final After Adjustments : This value represents the Basic Tension Embedment Length multiplied by all of the adjustment factors specified above.

Splice Lengths

Splice lengths per ACI 12.15 for tension and ACI 12.16 for compression are calculated for the reinforcing.

Sample Printout

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Title : ENERCALC Example Problems **Job #** 97-000001
Dsgnr: MDB **Date:** 11:24PM, 26 OCT 03
Description : Collection of example problems
Scope : All programs in the Structural Engineering Library

Rev: 580000
 User: K:\0000001, Ver 5.8.0, 10-Sep-2003
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 c:\ec56\examples.ecw\Concrete_Calcs

Description Several bars with different embedment conditions

Bar #1 : Using ACI 318-91 Methods

Bar Size	# 4	Rebar Area	0.200 in
f'c	3,000.00 psi	Class A Splice	16.43 in
Fy	60,000.00 psi	Class B Splice	21.36 in
		Compression Splice	15.00 in
Straight Embedment			
ACI 12.2.3.1 :	1	Tension Embedment...	
Lightweight Concrete ?	No	Basic Before Adjustments	8.764 in
Is it a TOP Bar ?	No	Final after adjustment	16.432 in
As req'd / As actual	1.000	Compression Embedment...	
Within Ties/Stirrups ?	No	Basic Before Adjustments	10.954 in
		Final after adjustment	10.954 in
Hooked Embedment...			
Adequate Cover ?	Yes	Basic Before Adjustments	10.954 in
Epoxy Coated ?	Yes	Final after adjustment	9.202 in
Lightweight Concrete ?	No		

Bar #2 : Per ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Bar Size	# 5	Rebar Area	0.310 in
f'c	3,000.00 psi	Class A Splice	26.70 in
Fy	60,000.00 psi	Class B Splice	34.71 in
		Compression Splice	18.75 in
Straight Embedment			
Reinf. Location Factor (alpha)	1.3	Tension Embedment...	
Coating Factor (beta)	1	Final after adjustments	26.701 in
Lightweight Factor (lambda)	1	Compression Embedment...	
As req'd / As actual	1.000	Final after adjustments	13.693 in
Spacing/Diameter Ratio	2.500		
Hooked Embedment...			
Adequate Cover ?	Yes	Basic Before Adjustments	13.693 in
Epoxy Coated ?	Yes	Final after adjustment	11.502 in
Lightweight Concrete ?	No		

Bar #3 : Using ACI 318-91 Methods

Bar Size	# 6	Rebar Area	0.440 in
f'c	3,000.00 psi	Class A Splice	24.65 in
Fy	60,000.00 psi	Class B Splice	32.04 in
		Compression Splice	22.50 in
Straight Embedment			
ACI 12.2.3.1 :	1	Tension Embedment...	
Lightweight Concrete ?	No	Basic Before Adjustments	19.280 in
Is it a TOP Bar ?	No	Final after adjustment	24.648 in
As req'd / As actual	1.000	Compression Embedment...	
Within Ties/Stirrups ?	No	Basic Before Adjustments	16.432 in
		Final after adjustment	16.432 in
Hooked Embedment...			
Adequate Cover ?	Yes	Basic Before Adjustments	16.432 in
Epoxy Coated ?	Yes	Final after adjustment	13.803 in
Lightweight Concrete ?	No		

Part



3 Masonry Design Modules

The programs in this section provide analysis and design for structural elements made of concrete unit masonry.

Code References

Program modules for MASONRY design are designed to be in conformance with the ACI 530-02 Edition. Masonry design is performed using "Allowable Stress Design" analysis & design procedures using factored loads and reduced allowable capacities. Exception : The module titled "Slender Masonry Wall Design" uses an ultimate strength P-Delta analysis.

Masonry design procedures in these modules follow the following code requirements:

- Design procedures for masonry follow ACI 530-02 Chapter 2.
- **IBC 2003** Sections 2108.1 and 2901.1 reference ACI 530 for the design of masonry.
- **1997 UBC** Chapter 21 provisions are based on ACI 530.
- **2003 NFPA 5000** Section 35.1.8.4 references ACI-318 for the design of masonry.
- Load combinations are according to ACI 530-02 Chapter 2

Masonry Wall

Masonry Wall uses non P-Delta working stress design procedures. UBC load combination equations of dead, live, and short term loads at top and mid-height are used to determine adequacy. Items considered include special inspection, solid grouting, eccentric loads, rebar location, and parapet loads.

Slender Masonry Wall Design

Slender Masonry Wall Design provides design analysis according to 1994 UBC section 2108.2.4 which considers P-Delta effects on total moment and wall deflection, and uses ultimate strength concepts. Added lateral point and distributed loads may be applied to model jambs at openings. Special inspection, rebar location, seismic factors, wind loads, spacing of grouted cells, and eccentric/concentric vertical loads can be modified and included in analysis. The program iterates until deflection convergence is reached for both service and factored load cases.

Masonry Column Design

Masonry Column Design gives design calculations for masonry columns which may or may not be built within a wall. For conditions where a wall does exist, the column analysis can include the effect of tributary lateral wind or seismic loads. A single axial dead and live load with eccentricity is applied to the top. Allowable bending and axial stress is calculated using MIA equations, and combined stress results are given for all

combinations.

Flush Wall Masonry Column

Flush Wall Masonry Column is similar to the Masonry Column program, except this column is contained entirely within the wall thickness. Axial loads and lateral loads due to wind and seismic forces are included in the analysis. An assumed width based upon bearing length plus four times column thickness is used unless modified. Allowable bending and axial stress is calculated using MIA equations, and interaction equation results are given for four combination conditions.

Masonry Shear Pier Analysis

Masonry Shear Pier Analysis can analyze force distribution between collinear shear elements in walls based upon their relative rigidities. Each pier may have a fixed or pinned end, have differing height, length, and thickness, and be of different construction types. Based upon these parameters, a single lateral load is distributed between the piers and required shear and bending reinforcement is given.

Masonry Lintel Design

Masonry Lintel Design allows vertical, lateral, and perpendicular loads, flexible rebar locations, and fixed or pinned end conditions.

3.1 Masonry Wall

This program provides design and analysis of masonry walls subjected to a combination of axial uniform dead and live loads, eccentric uniform vertical dead and live loads, and lateral loads due to seismic or wind forces. For design of masonry walls using the UBC Slender Wall method, please use the program entitled Slender Masonry Wall Design to perform this type of design.

The user may specify wall and parapet height, added vertical loads, seismic factor or wind load, wall thickness and reinforcing, special inspection, and grout spacing. The program calculates the actual and allowable axial and bending stresses, and combines them using interaction equations for your review.

The working stress method is used to calculate allowable axial and bending stresses. Three load combinations are evaluated for both the top of the wall and mid-height stress analysis using the axial and bending interaction equations.

ENERCALC c:\ECSS\EXAMPLES.ECIV - Masonry Wall Design

Masonry Wall Design

Tools & Settings Help Print Cancel Save

General Loads Results Printing

Description Typical wall section

Wall Height 16.500 ft

Parapet Height 3.000 ft

Wall Thickness 8 in

Rebar Size 5

Rebar Spacing 16 in

Rebar Location Center Edge

Depth to Rebar 3.810 in

fm 1,500.0 psi

Fs 24,000.0 psi

Special Inspection

Solid Grouting

Wall : '94 UBC Seismic Factor Z (p Cp) or Similar 1997 UBC Factor Divided by 1.4 0.330

Load Duration Factor 1.330

Wall Wt Multiplier 1.000

Calc of Em = fm * 750.0

Use Grouting at Face Shells Only?

Block Type Lightweight Medium Wt Normal Wt

Summary Loads & Moments Design Values

Wall Design OK

Max. Bending + Axial Comp. Stress 296.62 psi
Allowable 329.18 OK

Max. Axial Only Compressive Stress 18.59 psi
Allowable 120.61 OK

Max Steel Bending Stress 11,050.82 psi
Allowable 31,920.00 OK

	Moment	Axial Load	Bending Stress		Axial Comp
	in-#	lbs	Steel	Masonry	psi
Top of Wall					
DL+LL	3,120.0	660.0	4,060.0	103.9	9.48
DL+LL+W	2,682.0	468.0	3,490.1	89.3	6.72
DL+LL+S	2,941.2	468.0	3,827.4	97.9	6.72
Between Base & Top of Wall					
DL+LL	1,560.0	1,155.0	2,030.0	51.9	16.59
DL+LL+W	6,668.1	963.0	8,677.1	222.0	13.84
DL+LL+S	8,492.2	963.0	11,050.8	282.8	13.84

Basic Usage

- Design Data should be entered to define the material strengths, inspection status, and grouting to be used for the wall. Also, the Lateral Load Factor can be used to specify either wind load or seismic factor (please see the specific description in the Detailed Item Summary section).
- The Wall & Load Data section allows you to specify wall heights and additional loads. The wall height can consist of a clear span and parapet extension, both of which will have seismic or wind loads applied. Uniform eccentric and concentric vertical loads can be applied to transfer roof, floor, or upper level loads to the wall.
- Wall Thickness, Rebar Size, Spacing, and Location can be entered and modified during the design process to bring actual stresses below allowable values.
- After entering the above information, calculate the calcsheet and review the Design Summary section. This section gives detailed analysis results for vertical and moment forces, steel and masonry stresses, and combined axial and bending stress results. Both the top of the wall and mid-height are investigated.
- You can also review the Allowable Stresses section to inspect the individual values used to calculate allowable bending and axial stress. The Vertical Loads & Moments section can also be reviewed to see how the dead, live, and lateral loads are combined to achieve the maximum stress results.
- When satisfied, you can Print or Save the data for the current calculation, Reset the calcsheet, or use the Access Menu to choose another program.

Unique Features

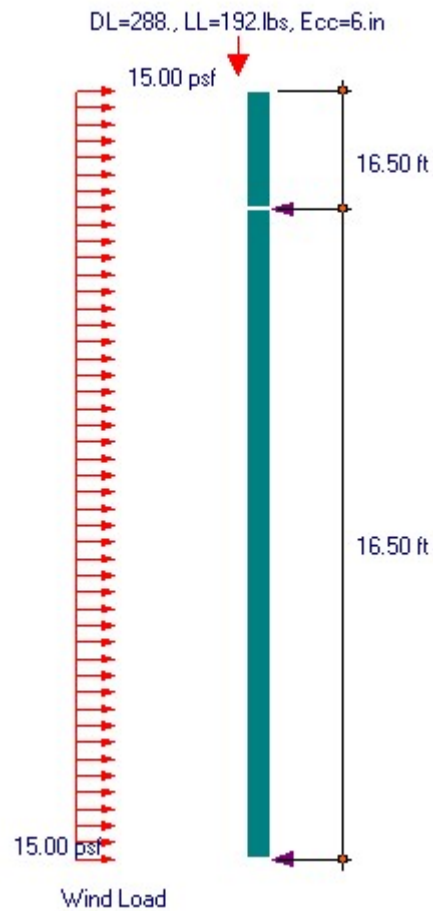
- This program permits quick evaluation of a masonry wall subjected to a variety of forces and varying materials and reinforcing.
- Both wind and seismic loads may be applied to the wall.
- The program provides detailed results of various combinations of dead, live, and lateral loads and their effect on moments at the top and mid-height wall sections.

Assumptions & Limitations

- A strip of wall one-foot in length is used for analysis, and all forces should be entered on a force per lineal foot basis.
- P-Delta effects are not considered. The conventional allowable axial stress formula considering slenderness is used.
- provisions for calculating allowable axial stress due to wall slenderness, allowable bending stresses in masonry and concrete, and calculation of actual axial and bending stresses.
- Live load can be specified as floor or roof. If specified as floor, it will always be included with wind/seismic analysis.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General		Loads
Description Typical wall section		
Wall Height	16.500	ft
Parapet Height	3.000	ft
Wall Thickness	8	in
Rebar Size	5	
Rebar Spacing	16	in
Rebar Location	<input checked="" type="radio"/> Center	<input type="radio"/> Edge
Depth to Rebar	3.810	in
fm	1,500.0	psi
Fs	24,000.0	psi
Special Inspection	<input type="checkbox"/>	
Solid Grouting	<input type="checkbox"/>	
Wall : '94 UBC Seismic Factor Z Ip Cp -or- Similar 1997 UBC Factor Divided by 1.4	0.330	
Load Duration Factor	1.330	
Wall Wt Multiplier	1.000	
Calc of Em = fm *	750.0	
Use Grouting at Face Shells Only ?	<input type="checkbox"/>	
Block Type	<input checked="" type="radio"/> Lightweight	<input type="radio"/> Medium Wt <input type="radio"/> Normal Wt

Wall Height
 The unsupported wall height is measured from the points of lateral support at the floor and roof/second floor. This distance is used to determine moments in the wall due to applied lateral seismic or wind loads.

Parapet Height
 This portion of the wall extends above the Clear Span Height and will apply a concentrated moment due to wind or seismic load to the top of the wall. Vertical load due to the parapet weight is also included.

Wall Thickness
 Enter the nominal wall thickness you are using or an estimate of what will be needed. A table of "d" values, equivalent solid thickness, and weights are stored in the program, and the appropriate value will be selected based upon nominal wall thickness. Thicknesses allowed are 6", 8", 10", 12", 14", and 16" inches.

Rebar Size
 The user enters choice of rebar to be used in the analysis. Rebar area recalled from a typical table. #3 through #11 bars are allowed (#14 and #18 will cause the program to not calculate).

Rebar Spacing

The rebar spacing entered here applies to the rebar size entered above. Please be sure to enter the spacing as it applies to the block modules being used! Only 8", 16", 24", 32", 40", and 48" inches are allowed.

Rebar Location

Select if the vertical reinforcement will be located at the centerline of the wall at the outside edge.

NOTE: If reinforcing is stated to be at each face, two layers of rebar will not be used in the evaluation of section properties, only one bar at the d for bar placed at each face will be used.

Depth to Rebar

Enter the depth the program will use from the compression face to the centerline of the rebar.

f'm

Enter the allowable masonry strength to be used in the analysis. The allowable bending and axial stresses calculated from f'm are outlined in a later section. If the user has chosen not to use special inspection, both allowable axial and bending stresses will be multiplied by 1/2.

Fs

Enter the allowable tension strength of the reinforcing to be used. This value will be used as entered to determine the interaction equations for the design being performed.

Special Inspection

In this location, specify YES if special inspection will be used, allowing full f'm based masonry stresses to be used. Entering NO specifies that no special inspection will be performed, and all allowable stresses will be reduced by 1/2.

Solid Grouting

Enter YES if the wall will be solid grouted (regardless of steel spacing). Entering NO specifies that only cells containing vertical reinforcing will be grouted. This input effects the calculation for wall weight and equivalent solid thickness.

Wall Seismic Factor

The seismic factor will be applied to the actual wall weight to generate the lateral load for seismic analysis.

Wall Weight Multiplier

This factor is available for you to modify the wall weight recalled from the internal tables. The value will be applied directly to the internal wall weight and the product displayed as Wall Weight.

Calc of Em = f'm * (value)

In masonry construction the value of Em (Elastic Modulus of the masonry) is calculated as a multiplier applied to f'm. Enter that multiplier here.

Use Grouting at Face Shells Only ?

This item tells the program whether to calculate equivalent solid thickness using just the face cells with grout in the bedding or that all block surfaces that mate with the next block above or below have a grout bed.

Block Type

This entry controls what block type is being used for determining the wall weight to be recalled from the internal tables. Select Lightweight, Medium Weight, or Normal Weight.

Loads Tab

General		Loads	
Wind Load		<input type="text" value="15.000"/>	psf
Uniform Load			
Dead Load		<input type="text" value="288.00"/>	#/ft
Live Load		<input type="text" value="192.00"/>	#/ft
Load Eccentricity		<input type="text" value="6.500"/>	in
Uniform Load Type		<input checked="" type="radio"/> Roof Load	<input type="radio"/> Floor Load
Concentric Axial Load			
Dead Load		<input type="text"/>	#/ft
Live Load		<input type="text"/>	#/ft
Concentric Load Type		<input checked="" type="radio"/> Roof Load	<input type="radio"/> Floor Load

Wind Load

This wind load will be applied to the wall to determine moments for wind load analysis.

Uniform Loads

These uniform loads are vertically applied to the wall at the specified eccentricity. The program resolves this loading to an axial load and concentrated moment applied at the top of the Clear Span Height. The concentrated moment is assumed to decrease to zero at the lower lateral support. This load is included in both bending and axial load computations.

Uniform Load Eccentricity

The user may specify that the uniform dead and live load is applied at an eccentricity. When determining maximum moments, the moment created by the uniform load is always ADDED to the lateral load moments, regardless of whether eccentricity is positive or negative.

Uniform Type

This flag specifies whether the uniform load is due to roof or floor loadings. When floor is used, the uniform live load will be included in wind and seismic analysis combinations.

Concentric Axial Load

The user can specify an axial load applied to the top of the wall, such as load carried down from a floor above or just an added load. This load is considered axial stress only. (No P-Delta moments calculated).

Concentric Load Type

This flag specified whether the axial load is due to roof or floor loadings. When floor is used, the axial live load will be included in wind and seismic analysis combinations.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information

on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results / Summary Tab

This section provides a detailed breakdown of the forces and stresses on the wall. Various load combinations are provided at the top and mid-height of the wall to evaluate maximum stresses.

Summary		Loads & Moments		Design Values	
Wall Design OK					
Max. Bending + Axial Comp. Stress				296.62	psi
Allowable				329.18	OK
Max. Axial Only Compressive Stress				16.59	psi
Allowable				120.61	OK
Max Steel Bending Stress				11,050.82	psi
Allowable				31,920.00	OK
		Axial	<u>Bending Stress</u>		Axial
	Moment	Load	Steel	Masonry	Comp.
Top of Wall	in-#	lbs	psi	psi	psi
DL+LL	3,120.0	660.0	4,060.0	103.9	9.48
DL+LL+W	2,682.0	468.0	3,490.1	89.3	6.72
DL+LL+S	2,941.2	468.0	3,827.4	97.9	6.72
Between Base & Top of Wall					
DL+LL	1,560.0	1,155.0	2,030.0	51.9	16.59
DL+LL+W	6,668.1	963.0	8,677.1	222.0	13.84
DL+LL+S	8,492.2	963.0	11,050.8	282.8	13.84

Maximum Values Summary

The area at the top of this tab shows the maximum stress values for the wall, allowable values, and an OK/NG indicator.

Results / Loads & Moments Tab

This table gives the various moments calculates in the wall, the total dead & live loads, and some back-calculated maximum values for moments and axial loads.

Summary	Loads & Moments	Design Values
Dead Load Moment @ Top of Wall	1,872.00 in-#	
Dead Load Moment @ Mid Ht	936.00 in-#	
Live Load Moment @ Top of Wall	1,248.00 in-#	
LiveLoad Moment @ Mid Ht	624.00 in-#	
Wind Moment @ Mid Ht	5,727.32 in-#	
Seismic Moment @ Mid Ht	7,560.06 in-#	
Wall Weight Moment @ Mid Ht	675.00 lbs	
Total Dead Load	288.00 lbs	
Total Live Load	192.00 lbs	
Maximum Allow Moment for Applied Axial Load =	7,432.64 in-#	
Maximum Allow Axial Load for Applied Moment =	8,394.19 lbs	

Results / Design Values Tab

Summary	Loads & Moments	Design Values
Allowable Stresses . . .		
<i>(Multiply by Load Duration Factor for Wind & Seismic)</i>		
Max Allow Axial Stress = $0.25 f'm (1-(h/140r)^2) * Splns$		120.61 psi
Allowable Masonry Bending Stress . . .		
$(f'm / 3) * Load Dur Factor * (.5 if no Splnsp) . . .$		247.50 psi
Allow Steel Bending Stress		24,000.00 psi
Equivalent Solid Thickness		5.800 in
E		1,125,000 psi
$n=Es/Em$		25.778
Wall Wt		60.000 psf
As		0.233 in ²
np		0.13109
k		0.39746
j		0.86751
$2 / kj$		5.80047
Radius of gyration		2.368 in
Moment of Inertia		390.21 in ⁴

Allowable Stresses

In this section the allowable axial, masonry bending, and steel bending stresses are given along with the equations used to create them.

Equiv. Solid Thickness

The equivalent solid thickness of the wall specified, depending on reinforcement spacing and status of solid grouting, is recalled from an internal table of values.

Em

The modulus of elasticity used is calculated as either (1000 -or- 750) * f'm. If special inspection is not used, Em is not reduced by 1/2.

$n = Es / Em$

Wall Weight

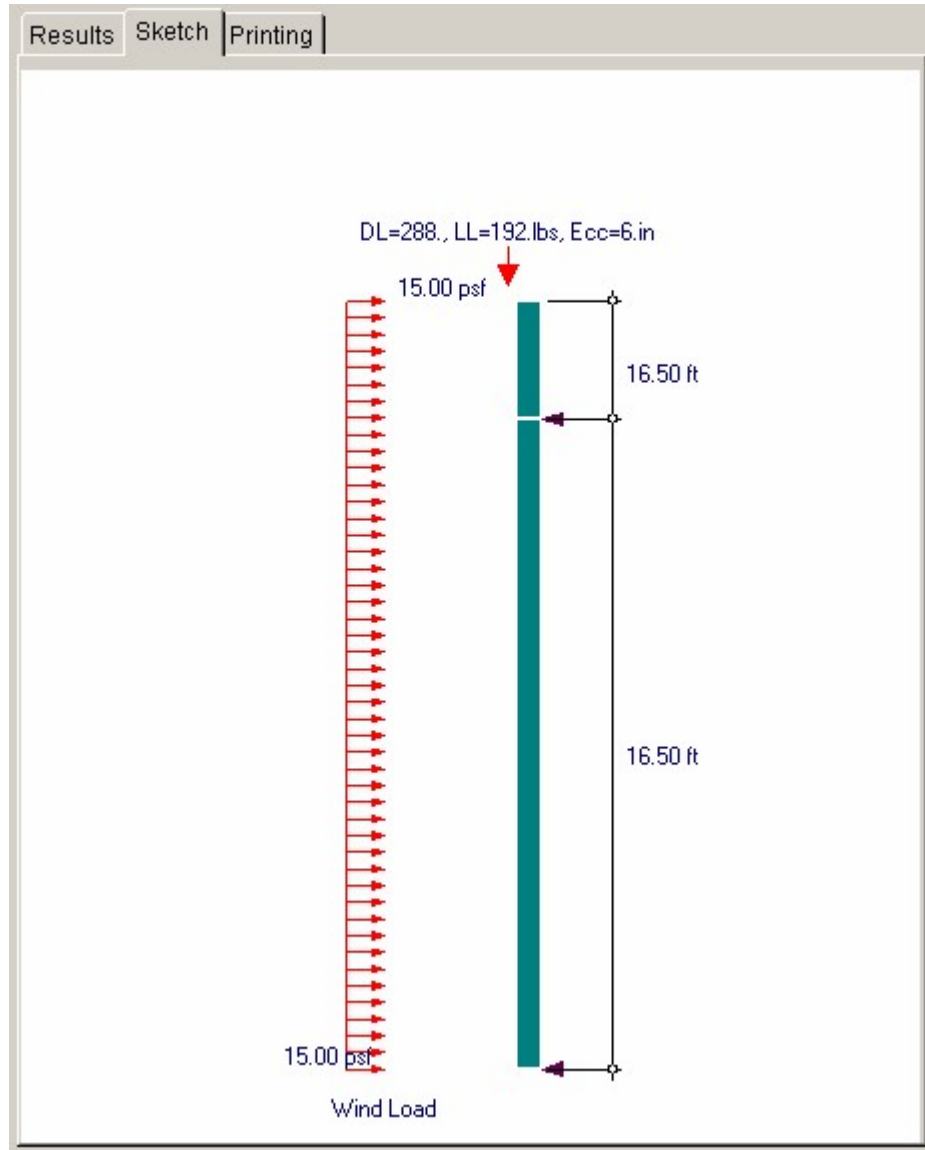
These include the wall weight from mid height of Clear Height to the top of the Parapet.

As, np, k, j, 2/kj, Radius of Gyration, Moment of Inertia

These are additional design values for your reference.

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Loads	<input checked="" type="checkbox"/>
Design Values	<input checked="" type="checkbox"/>
Load Combination & Stress Details Summary	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Final Load & Moments	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title : ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 5:58PM, 28 OCT 03
 Description : Collection of example problems
 Scope : All programs in the Structural Engineering Library

Rev: 000000 User: 1993-2003 Ver 5.0.0, 10-Sep-2003 Page 1
 (c)1983-2003 ENERCALC Engineering Software Masonry Wall Design c:\ed58\examples.com\Masonry Calc

Description Typical wall section

General Information		Code Ref. ACI 530-02			
Wall Height	16.50 ft	Seismic Factor	0.3300	f'm	1,500.0 psi
Parapet Height	3.00 ft	Calc of Em = f'm *	750.00	Fs	24,000.0 psi
Thickness	8.0 in	Duration Factor	1.330	No Special Inspection	
Rebar Size	5	Wall Wt Mut.	1.000	Grout @ Rebar Only	
Rebar Spacing	16 in			Lightweight Block	
Depth to Rebar	3.810 in @ Center			Equivalent Solid Thickness 5.800 in	

Loads					
Uniform Load		Concentric Axial Load		Wind Load	15,000 psf
Dead Load	288.000 #/ft	Dead Load	0.000 #/ft		
Live Load	192.000 #/ft	Live Load	0.000 #/ft		
Load Eccentricity	6.500 in	Roof Load			
Roof Load					

Design Values							
E	1,125,000 psi	Rebar Area	0.233 in ²	np	0.13109	j	0.86751
n : Es / Em	25.778	Radius of Gyration	2.388 in	k	0.39746	2 / kj	5.80047
Wall Weight	60.000 psf	Moment of Inertia	390.210 in ⁴				
Max Allow Axial Stress = 0.25 f'm (1-(h/140r) ²) * Sp/insp				120.61 psi			
Allow Masonry Bending Stress = 0.33 f'm * Sp/insp =				247.50 psi			
Allow Steel Bending Stress =				24,000.00 psi			

Load Combination & Stress Details Summary					
	Moment	Axial Load	Bending Stresses		Axial Compression
	in-#	lbs	Steel	Masonry	psi
Top of Wall			psi	psi	psi
DL + LL	3,120.0	660.0	4,060.0	103.9	9.48
DL + LL + Wind	2,682.0	468.0	3,490.1	89.3	6.72
DL + LL + Seismic	2,941.2	468.0	3,827.4	97.9	6.72
Between Base & Top of Wall					
DL + LL	1,560.0	1,155.0	2,030.0	51.9	16.59
DL + LL + Wind	6,668.1	963.0	8,677.1	222.0	13.84
DL + LL + Seismic	8,492.2	963.0	11,050.8	262.8	13.84

Summary	
16.50ft high wall with 3.00ft parapet, Lt Wt Block w/ 8.00in wall w/ #5 bars at 16.00ino.c. at center	
Max. Bending Compressive Stress	296.62 OK
Allowable	329.18 OK
Max. Axial Only Compressive Stress	16.59 psi
Allowable	120.61 OK
Max Steel Bending Stress	11,050.82 psi
Allowable	31,920.00 OK

ENERCALC Engineering Software
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 Dsgnr: MDB Date: 5:58PM, 28 OCT 03
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 Scope: All programs in the Structural Engineering Library

Rev: 080000
 Us er: KW-0000001, Ver 5.8.0, 10-9-03-2003
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Masonry Wall Design

Page 2

c:\e05\examples.eov\Masonry Calc

Description Typical wall section

Final Loads & Moments

Wall Weight moment @ Mid Ht	675.00 lbs	Wind Moment @ Mid Ht	5,727.32 in-#
		Seismic Moment @ Mid Ht	7,560.06 in-#
Dead Load Moment @ Top of Wall	1,872.00 in-#		
Dead Load Moment @ Mid Ht	936.00 in-#	Total Dead Load	288.00 lbs
Live Load Moment @ Top of Wall	1,248.00 in-#	Total Live Load	192.00 lbs
LiveLoad Moment @ Mid Ht	624.00 in-#		
Maximum Allow Moment for Applied Axial Load =		7,432.64 in-#	
Maximum Allow Axial Load for Applied Moment =		8,394.19 lbs	

3.2 Slender Wall

This program provides design and analysis according to the new provisions for design of masonry walls, using the P-Delta deflection considerations now included in the UBC. This method lifts the restriction on H/t ratios, and performs wall analysis using the principles of ultimate strength design. The design method is very similar to that of the Tilt-Up Wall Panel Strip design program contained in the concrete section.

This program uses a 12" wide strip of wall section to represent a typical section of wall. All lateral loads must be adjusted so that the loads acting on the 12" wide section are representative of actual loadings. The program has the ability to apply a lateral wind

load, seismic load, partial length uniform lateral load, and a lateral point load to the clear span of the wall section. This variety of loadings should take care of almost every lateral loading case possible.

The P-Delta design of the wall uses a two-stage deflection behavior. For further reference into this design method, please see the UBC or the revised codes from the Masonry Institute of America.

The user may specify masonry and reinforcing strengths, seismic factor, wind load, vertical and lateral loads, vertical load eccentricities, and wall construction. The program determines the wall capacity, actual deflections considering P-Delta effects, and solves for the final moments obtained through iteration of the P-Delta effects. Deflection analysis is provided for both service and factored load cases.

The user reaches a final design by modifying wall thickness, rebar size, and rebar spacing until no overstress condition exists and the deflection limits prescribed in the code are satisfied.

Wall Design OK

Factored Load Bending Analysis : Seismic Load Governs
 Maximum Iterated Moment : Mu 19,870.80 in-#
 Moment Capacity : Mn * Phi 54,972.80 in-#

Service Load Deflection Analysis : Seismic Load Governs
 Maximum Iterated Deflection 0.236 in
 Deflection Limit (Using Specified Ratio) 1.470 in

	Seismic	Wind
Mn * Phi : Moment Capacity	54,972.6	54,972.60 in-#
Mu : (0.9D+1.43E),(0.9D+1.3W)	19,870.8	9,463.0 in-#
Mu : (1.05D+1.275L) + [1.403E-or-1.275W]	19,632.8	9,374.4 in-#
Overstress	0.000 %	0.000 %
Allow Deflection: 0.007 * Height	1.470	1.470 in
Max Iterated Service Load Deflection	0.236	0.065 in
Actual Deflection Ratio	888.6 : 1.0	3,236.9 : 1.0
Actual Reinforcing Percentage	0.0037 %	0.0037 %
Allowable Max. Reinf. Percent = 0.5 * Rho Bal	0.0053 %	0.0053 %
Actual Axial Stress : (Pw + Po) / Ag	9.99	9.99 psi
Allowable Axial Stress = 0.04 * fm	60.00	60.00 psi

Basic Usage

- Entering Stress Data will define the material strengths, grouting status, inspection status, and the values defining lateral seismic and wind loads. The Wall Weight

Factor is used as a multiplication factor on the internally stored wall weights (see specific item).

- The Wall Data section is used to enter the clear span, thickness, and reinforcing. These values can be continually modified during the design process to achieve a satisfactory design (satisfying both stress and deflection criteria).
- Vertical Loads can be applied to the wall, both eccentrically and concentrically with the wall centerline. These loads allow you to specify roof loads and additional loads due to equipment platforms or an extended wall segment above the top of the wall.
- Lateral Uniform or Point Loads can be applied to the wall strip, which can be used to simulate lintel-to-jamb loads. These lateral loads can be due to either wind or seismic forces.
- The above entries are all that are required to completely specify a wall section. Calculating the program will perform a factored load analysis for maximum moments and a service load analysis to determine maximum deflections. This analysis is executed simultaneously for both wind and seismic load cases.
- You can then proceed to Check Actual And Allowable Moments, deflection ratios, reinforcing percentages, and axial stress levels. If any are not within limits, you can modify reinforcing or wall thickness to bring the actual values into compliance.

Unique Features

- This program provides the ability to design tall, slender masonry walls according to the latest UBC Section 2411 provisions.
- Both seismic and wind analyses are performed at once.
- You can apply additional lateral loads to the wall to model lintel-to-jamb type conditions.

Assumptions & Limitations

- You should be fully aware of this design procedure for masonry walls. It yields designs that give tall thin walls less reinforcing than earlier working stress methods (where Height/Thickness ratios were limited to 36).
- This program uses ultimate strength principles for the analysis and deflection determination of the wall section.
- Deflection is determined using a two stage load-deflection curve. The deflection of the wall when the moment is LESS than the cracking moment will be based on the gross moment of inertia. To obtain deflections beyond that point, the difference between actual moment and cracking moment is applied using the cracked section moment of inertia. This load-deflection behavior is based on an extensive testing program that led to the adoption of this new design method in the UBC.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.

Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General Loads	
Description	Typical wall section
Wall Height	17.500 ft
Thickness	8 in
Rebar Size	5
Rebar Spacing	16 in
Rebar Location	<input type="radio"/> Center <input checked="" type="radio"/> Edge
fm	1,500.0 psi
Fy	60,000.0 psi
fr Multiplier (modulus of rupture multiplier)	2.5
Phi	0.80
Note! Special Inspection ALWAYS Required	
Wall : Service Seismic Factor Z Ip Cp -or- similar strength design factor divided by 1.4 .	0.300
Load Factoring	<input checked="" type="radio"/> 1994 & Earlier UBC <input type="radio"/> 2003 IBC / NFPA
Wall Wt Multiplier	1.000
Soild Grouted ?	<input type="checkbox"/>
Block Type	<input type="radio"/> Light <input checked="" type="radio"/> Medium <input type="radio"/> Normal

Wall Height

The unsupported wall height is measured from the points of lateral support at the base and roof/second floor. This distance is used to determine moments in the wall due to applied lateral seismic or wind loads.

Thickness

Wall thickness to be used in design analysis. Please enter the NOMINAL thickness; Internal tables will evaluate the actual thickness to be used in the calculations. Thickness can be 6", 8", 10", 12", 14", and 16" inches.

Rebar Size

Enter the rebar size number which should be used. Note that rebar area is not calculated, but recalled from an internal table (#11 and #14 bars are not allowed).

Rebar Spacing

This indicates the 8" Module rebar spacing to be used for design analysis.

Rebar Location

Select Center or Edge. The actual rebar depth will automatically be retrieved from an internal table.

f'm

This is the allowable masonry strength used in the analysis. The allowable bending and axial stresses calculated from f'm are outlined in a later section.

Fy

Enter the allowable tension strength of the reinforcing to be used. This value will be used as entered to determine the interaction equations for the design being performed.

fr Multiplier

Enter the multiplier to be applied to f'm to calculate the modulus of rupture.

Phi

The value for Phi (capacity reduction factor) is dependent upon special inspection. 0.80 is used for inspected construction, 0.50 for uninspected. This capacity reduction factor is applied to the calculated moment capacity to take into account such factors as quality control, use, and design/analysis assumptions.

Wall Seismic Factor

The seismic factor will be applied to the actual wall weight to generate the lateral load for seismic analysis.

Load Factoring per Code

Select the core that will govern the internal factoring of entered loads for calculation of ultimate (factored) loads applied to the wall.

Wall Weight Multiplier

This factor is available for you to modify the wall weight recalled from the internal tables. The value will be applied directly to the internal wall weight and the product displayed as Wall Weight.

Solid Grouted?

Enter YES if the wall will be solid grouted (regardless of steel spacing). Entering NO specifies that cells containing vertical reinforcing will be grouted. This input effects the calculation for wall weight and equivalent solid thickness

Block Type

This entry controls what block type is being used for determining the wall weight to be recalled from the internal tables. Select Lightweight, Medium Weight, or Normal Weight.

Loads Tab

General		Loads	
Wind Load		<input type="text" value="15.00"/>	psf
Vertical Loads...			
Uniform Dead Load		<input type="text" value="144.00"/>	#/ft
Uniform Live Load		<input type="text" value="192.00"/>	#/ft
Eccentricity		<input type="text" value="7.000"/>	in
Load Type		<input checked="" type="radio"/> Roof	<input type="radio"/> Floor
Concentric Dead Load		<input type="text"/>	#/ft
Concentric Live Load		<input type="text"/>	#/ft
Load Type		<input type="radio"/> Roof	<input checked="" type="radio"/> Floor
Lateral Loads...			
Point Load		<input type="text"/>	lbs
Height		<input type="text" value="0.000"/>	ft
Load Type		<input type="radio"/> Wind	<input type="radio"/> Seismic
Distributed Load		<input type="text" value="25.00"/>	#/ft
Dist. to Top		<input type="text" value="17.500"/>	ft
Dist. to Bottom		<input type="text" value="10.000"/>	ft
Load Type		<input type="radio"/> Wind	<input checked="" type="radio"/> Seismic

Wind Load

Enter the wind load (in psf) that should be applied laterally to the full height of the wall. This load will be combined with any added lateral loads that are specified as Wind.

Vertical Loads

Uniform Loads

These uniform loads are applied to the wall at the specified eccentricity. The program resolves this loading to an axial load and concentrated moment applied at the top of the Unsupported Height. The concentrated moment is always ADDED to the moments created from wind and seismic forces, and decreases to zero at the lower lateral support. This load is included in both bending and axial load computations.

Uniform Load Eccentricity

The user may specify that the uniform dead and live load is applied at an eccentricity. When determining maximum moments, the moment created by this eccentric load is always ADDED to the lateral load moments, regardless of whether eccentricity is positive or negative.

Concentric

You can specify an axial load applied to the top of the wall, such as load carried down from a floor above or just an added load. This load is considered axial stress only. (No P-Delta moments calculated).

Lateral Loads**Point Lateral Load**

This load is applied to the 12" wide strip of wall in addition to the lateral load due to wind and seismic forces. If it is a seismic load, the value should be entered after applying the code specified seismic factor . This additional lateral load is intended to enable the user to model a section of wall or Jamb Strip when additional loads are applied to it (e.g. from a lintel contributing lateral wind/seismic load to a jamb strip through a horizontal bond beam at the opening head).

Height From Base

Enter the distance from the bottom of the wall to point of application of the concentrated point load.

Point Type: Wind/Seismic

This specifies whether this added point load is due to seismic or wind forces.

Uniform Lateral Load

This load is applied to the 12" wide strip of wall in addition to the lateral load due to wind or seismic forces. For seismic loads, it should be entered after applying the code required seismic factor . This additional lateral load enables the user to model a section of wall or jamb strip when additional loads are applied to it, (i.e. due to a lintel spanning horizontally, constructed integrally with the wall).

X-distance To Bottom

Enter the distance from the bottom of the wall to the start of the uniform lateral load.

X-Distance To Top

Enter the distance from the bottom of the wall to the end of the uniform lateral load. This height will be automatically limited to Unsupported Height if it has been specified as greater.

Uniform Type: Wind/Seismic

This specifies whether this added uniform lateral load is due to seismic or wind forces.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results / Summary Tab

Results Sketch Printing		
Summary P-Delta Analysis Analysis Values		
Wall Design OK		
Factored Load Bending Analysis : Seismic Load Governs		
Maximum Iterated Moment : Mu		19,870.80 in-#
Moment Capacity : Mn * Phi		54,972.60 in-#
Service Load Deflection Analysis : Seismic Load Governs		
Maximum Iterated Deflection		0.236 in
Deflection Limit (Using Specified Ratio)		1.470 in
	<u>Seismic</u>	<u>Wind</u>
Mn * Phi : Moment Capacity	54,972.6	54,972.60 in-#
Mu: (0.9D+1.43E),(0.9D+1.3W)	19,870.8	9,463.0 in-#
Mu: (1.05D+1.275L) + [1.403E-or- 1.275W]	19,632.8	9,374.4 in-#
Overstress	0.000 %	0.000 %
Allow Deflection: 0.007 * Height	1.470	1.470 in
Max Iterated Service Load Deflection	0.236	0.065 in
Actual Deflection Ratio	888.6 : 1.0	3,236.9 : 1.0
Actual Reinforcing Percentage	0.0037 %	0.0037 %
Allowable Max. Reinf. Percent = 0.5 * Rho Bal	0.0053 %	0.0053 %
Actual Axial Stress : (Pw + Po) / Ag	9.99	9.99 psi
Allowable Axial Stress = 0.04 * fm	60.00	60.00 psi

M-n * Phi

From the analysis presented in the section titled Analysis Values, the maximum moment capacity of the wall for both seismic and wind loading is displayed.

M-u

From the analysis to follow, the maximum factored load moment acting on the wall from both seismic and wind loads is displayed.

Maximum Overstress

If the wall section you have specified exceeds the actual moment, the percentage of overstress is listed.

Maximum Allowable Deflection

The maximum allowable deflection per code is .007 * Clear Wall Height (distance between lateral supports). Your design should always be checked so that this requirement is satisfied, since the deflection limitation design philosophy is the primary factor allowing slender masonry walls.

Max. Iterated Service Deflection

This is the calculated deflection at the mid-height of the wall using service loads. The program

calculates this deflection by iterating P-Delta moments and the resulting increase in deflections caused by these moments.

Actual Ht /Service Deflection

For both seismic and wind loading cases, the clear wall height is divided by the Service Load Deflection @ Convergence.

Actual Reinf. %

This is the actual reinforcing percentage ratio for the rebar and wall thickness specified.

Allowable %

This is the maximum allowable steel percentage by UBC code and varies with grade of steel.

Actual Axial Load

This is the actual axial stress on the 12" wide strip, caused by the applied vertical loads and wall weight ABOVE mid-height. When the wall is partially grouted, the equivalent solid thickness is used to calculate the area instead of the actual wall thickness.

Allowable Axial Load

The allowable axial load that can be imposed on the 12" wall section subjected to bending is $.04 * f'm$ * AGROSS. This allowable axial load is listed here for comparison with the actual value listed below. The designer should always verify that this allowable load is greater than the actual load.

Results / P-Delta Analysis Tab

Results Sketch Printing		
Summary P-Delta Analysis Analysis Values		
Factored Load Analysis		
	<u>Seismic</u>	<u>Wind</u>
Basic Moment without P-Delta	19,648.97	9,411.41 in-#
Basic Deflection without P-Delta	0.44	0.08 in
Moment in excess of Cracking Moment	9,738.96	0.00 in-#
Max. Iterated Wall Deflection	0.44	0.08 in
Max. Iterated Wall Moment	19,870.80	9,463.04 in-#
Static Load Analysis		
	<u>Seismic</u>	<u>Wind</u>
Basic Moment without P-Delta	13,964.70	7,394.62 in-#
Basic Deflection without P-Delta	0.23	0.06 in
Moment in excess of Cracking Moment	4,054.69	0.00 in-#
Max. Iterated Wall Deflection	0.24	0.06 in
Max. Iterated Wall Moment	14,096.14	7,439.73 in-#

Factored and Service Load Stress Analysis

These two sections provide the details of the iterative analysis of the wall section using factored and service loads. The factored load analysis is used to determine maximum moments in the wall, accrued by iterative recalculation of deflections and their effect on P-Delta moments.

The service load analysis uses unfactored loads to iterate wall deflections and moments. The Height/Service Deflection ratio will be checked against the allowable limit.

Both methods follow the same procedure; calculate moment, calculate deflection, and then recalculate wall moments. UBC formula 11-7 is used to calculate moments and deflections:

$$MU = WU \cdot H^2/8 + POU \cdot e/2 + (PWU + POU) \cdot DU$$

$$DS-MAX \leq 0.007 \cdot \text{Wall Height}$$

$$DS = 5 \cdot MCRACKED \cdot h^2 / (48 \cdot EM \cdot IG) + 5 \cdot (MS - MCR) \cdot h^2 / (48 \cdot EM \cdot ICR)$$

The second term of the deflection equation is ignored when negative.

Basic Moment w/o P-delta

This is the mid-height moment induced from lateral seismic and wind loads and roof loads applied at an eccentricity before addition of P-Delta effects.

Basic Deflection w/o P-delta

Basic deflection is calculated using the basic moments applied to the equation presented above. For

moments up to the cracking moment, the gross moment of inertia is used to find deflection. For any portion of the moment that exceeds the cracking moment, the cracked section moment of inertia is used to determine additional deflections.

Basic Deflection w/o Excess Moment

If the basic moment is greater than the cracking moment ($SGROSS*FR$), the excess portion must be identified so a proper deflection analysis can be performed.

Maximum Iterated Deflection

After the repeated iteration of moment and deflection, the final value of deflection (that causes negligible additional deflection) is listed here.

Maximum Iterated Moment

The total moment at deflection convergence is calculated by iteration. Starting with the basic load deflection, the P-Delta moment is found and a subsequent deflection calculated (using the same "compound" moment of inertia method).

Results / Analysis Values Tab

The following values are used for the design and analysis of slender masonry walls. All of these values apply for both wind and seismic analysis with the exception of Moment of Inertia:Effective, which is different due to different A_{EFF} values being based on different factored axial loads.

Results		Sketch	Printing
Summary		P-Delta Analysis	Analysis Values
Equivalent Solid Thickness	5.80 in		
Gross Area	69.60 in		
A-steel	0.23 in ²		
As - Percent	0.0037		
As-Effective = (Pu + As * Fy) / Fy			
As-eff : Wind	0.245 in ²		
As-eff : Seismic	0.245 in ²		
'a' : Compression Block			
'a' : Wind	0.96 in		
'a' : Seismic	0.96 in		
Rebar "d" Distance	5.25 in		
Wall Weight	63.00 psf		
Wall Weight * Seismic Factor	18.90 psf		
Mn = Phi * As-eff * Fy * (d-a/2)			
Wind	54,972.60 in-#		
Seismic	54,972.60 in-#		
Em = 900 * fm	1,350,000 psi		
n = 29E6 / Em	21.48		
Fr = 2.5 * (fm) ^{0.5}	96.82 psi		
Sgross	102.35 in ³		
Mcracking = Sgross * Fr	9,910.01 in-#		
I-Gross	390.21 in ⁴		
I-Cracked - Wind	95.02 in ⁴		
I-Cracked - Seismic	95.02 in ⁴		
Phi: Wind =	0.800	Phi: Seismic =	0.800

Equivalent Thickness

The equivalent solid thickness depends upon NOMINAL the wall thickness and rebar spacing, and is obtained from a table stored within the program. When the wall has been specified as solid grouted (see item previous), this thickness is equal to the actual, not nominal, wall thickness. Please see table on page M-8

Gross Area

Gross area of the 12" wide strip equals Equivalent Solid Thickness * 12".

As

Reinforcing steel area in a 12" length of wall.

Asteel/Agross

This value is: As/Awall-EFFECTIVE

As-eff.

This is the steel reinforcing area in a 12" length of wall modified for the effect of axial load using the

UBC equation specified in section 2312:
 $AS-EFF = (AS \cdot f_Y + PU) / f_Y$

"a"

This is the typical ACI equation for determining the depth of the equivalent compressive stress block used for analysis.

Mn

This is the calculated maximum moment capacity of the section whose values for allowable stresses, reinforcing size and spacing, and effective area of steel are given.

Em

The modulus of elasticity for masonry is calculated as:

$$EM = 750 \cdot f'm$$

Fr

The modulus of rupture is calculated by multiplying the value you've entered by $f'm^{1/2}$

S-gross

Gross section modulus for 12" of wall width :
 $12" \cdot (\text{Actual Wall Thickness})^2 / 6$

S * Fr

This is the Cracking Moment, the maximum moment the wall can take as a solid section without any reinforcing.

Igross & Icracked

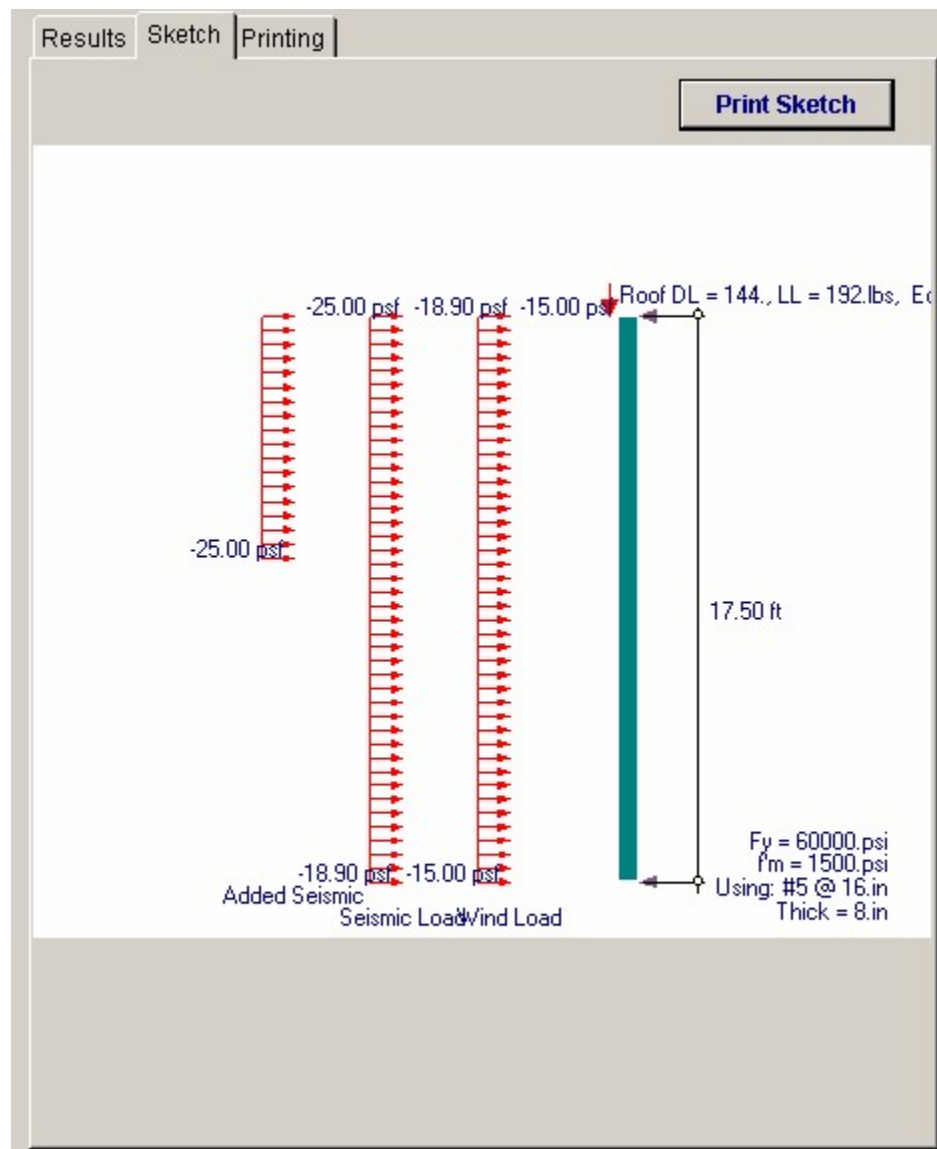
Gross and cracked section moduli of the wall to be used in the deflection analysis.

Wall Weight

The wall weight is automatically recalled from an internal table of weights, considering rebar spacing, wall thickness, and status of solid grouting. The table is based on light, medium, and normal weight block.

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Loads	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
P-Delta Analysis	<input checked="" type="checkbox"/>
Analysis Values	<input checked="" type="checkbox"/>
Load Summary	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 6:02PM, 28 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 500.000 User: KYW0000001, Ver: 5.0.0, 10-Sep-2003 (c)1983-2003 ENERCALC Engineering Software **Slender Masonry Wall** Page 1
 c:\e20\examples\slender Masonry Calc

Description Typical wall section

General Information Calculations are designed to 1994 UBC Requirements

Wall Height	17.50 ft	f'm	1,500.0 psi
Thickness	8.0 in	f _y	60,000.0 psi
Rebar Size	5	Wall Wt Multiplier	1.00
Rebar Spacing	16 in	Medium Weight Block	
Rebar Location	Edge	F _r = 2.5 * (f _m) ^{0.5}	2.50
Grouted Cells w/ Bars Only		Seismic Factor	0.300

Loads

Vertical Loads...		Wind Load (full height)	15.00 psf
Uniform Eccentric Load...		Lateral Loads...	
Dead Load	144.00 #/ft	Point Load	0.00 lbs
Live Load	192.00 #/ft	@ height	0.00 ft
Eccentricity	7.00 in	Seismic	
Roof		Distributed Load	25.00 #/ft
Concentric Load...		Dist. to Top	17.50 ft
Dead Load	0.00 #/ft	Dist. to Bottom	10.00 ft
Live Load	0.00 #/ft	Seismic	
Floor			

Summary Wall Design OK

17.50ft high, 8.00in thick w/ #5 bars at 16.00in on center at edge, MedWt Block
 f'm = 1,500.0psi, F_y = 60,000.0psi, Special Inspection Req'd, Grout @ Rebar Only

Factored Load Bending	: Seismic Load Governs	Service Load Deflection	: Seismic Load Governs
Maximum Iterated Moment : Mu	19,870.80 in-#	Maximum Iterated Deflection	0.236 in
Moment Capacity	54,972.60 in-#	Deflection Limit	1.470 in

Seismic	Wind
Mn * Phi : Moment Capacity	54,972.6 in-#
Mu : (0.9D+1.43E) (0.9D+1.3W)	19,870.8 in-#
Mu : (1.05D+1.275L) + [1.403E-or- 1.275W]	9,463.0 in-#
Overstress Percentage	9,374.4 in-#
	0.00
Allow Deflection: 0.007 * Height	1.470 in
Max Iterated Service Load Deflection	0.236 in
Actual Deflection Ratio	0.065 in
	888.6
	3,236.9
Actual Reinforcing Percentage	0.0037
Allowable Max. Reinf. Percent = 0.5 * Rho Bal	0.0053
	0.0053
Actual Axial Stress : (Pw + Po) / Ag	9.99psi
Allowable Axial Stress = 0.04 * f'm	60.00psi
	60.00 psi

P-Delta Analysis

Factored Load Analysis	Seismic	Wind
Basic Moment without P-Delta	19,648.97 in-#	9,411.41 in-#
Basic Deflection without P-Delta	0.44 in	0.08 in
Moment in excess of Cracking Moment	9,738.96 in-#	0.00 in-#
Max. Iterated Wall Deflection	0.44 in	0.08 in
Max. Iterated Wall Moment	19,870.80 in-#	9,463.04 in-#
Service Load Analysis	Seismic	Wind
Basic Moment without P-Delta	13,964.70 in-#	7,394.62 in-#
Basic Deflection without P-Delta	0.23 in	0.06 in
Moment in excess of Cracking Moment	4,054.69 in-#	0.00 in-#
Max. Iterated Wall Deflection	0.24 in	0.06 in
Max. Iterated Wall Moment	14,096.14 in-#	7,439.73 in-#

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Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 6:02PM, 28 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 580000 User: KW0500001 Ver 5.8.0, 10-Sep-2003 (c)1983-2003 ENERCALC Engineering Software Page 2
 c:\eo58\example.s.com\Masonry Calc

Slender Masonry Wall

Description Typical wall section

Load Summary

Vertical Load Summary...

DL @ Max. Mom Loc.	695.25 lbs
LL @ Max. Mom Loc.	0.00 lbs
0.9 * Dead Load	625.73 lbs
1.05 * Dead Load	730.01 lbs
1.275 * Live Load	0.00 lbs
Wall Weight	63.00 psf
Wall Weight * Seismic Factor	18.90 psf

Lateral Load Summary...

1.3 * Wind Load	19.50 psf
1.7 * Wind Load	25.50 psf
Seismic Factor * Wall Wt.	18.90 psf
1.43 * Seismic Weight	27.03 psf
1.87 * Seismic Weight	35.34 psf
Rebar "d" Distance	5.25 in

Analysis Values

Phi	0.80	Mn = Phi * As-eff * Fy * (d-a/2)	
Equivalent Solid Thickness	5.80 in	Wind	54,972.60 in-#
Gross Area	69.60 in	Seismic	54,972.60 in-#
A-steel	0.23 in ²	Em = 900 * fm	1350000.00 psi
As - Percent	0.0037	n = 29E6 / Em	21.48
As-Effective = (Pu + As * Fy) / Fy		Fr = 2.5 * (fm) ^{.5}	96.82 ps
As-eff : Wind	0.245 in ²	Sgross	102.35 in
As-eff : Seismic	0.245 in ²	Mcrracking = Sgross * Fr	9,910.01 in
'a' : Compression Block		I-Gross	390.21 in ⁴
'a' : Wind	0.96 in	I-Cracked - Wind	95.02 in ⁴
'a' : Seismic	0.96 in	I-Cracked - Seismic	95.02 in ⁴
		Phi: Wind	0.800
		Phi: Seismic	0.800

Roof DL = 144.0, LL = 192.00, Pos = 1.00h

Sketch & Diagram



3.3 Masonry Column

This program provides design and analysis for masonry columns, subjected to a combination of eccentric vertical and lateral loads due to seismic or wind forces.

You can apply an eccentric girder load to the top of the column, general uniform lateral

loads, and specify that tributary wall seismic and wind forces must be applied to the column. The program performs analysis of all combinations of dead, live, wind, and seismic forces to generate moments, stresses, and final design interaction values.

The user may specify allowable masonry and steel stresses, special inspection, seismic factor, wind load, unit weight of column material, unsupported height of column, and number and size of rebar at each face.

The analysis calculates allowable axial stresses considering both masonry and reinforcing capacities, and checks both steel and masonry bending stresses before combining them in the interaction values.

Masonry Column Design

Tools & Settings: ? Help, Print, Cancel, Save

General | Loads

Description: Column w/ additional later load : 2' -> 12'

Column Height: 15.000 ft
 Column Width: 12.000 in
 Column Depth: 16.000 in
 Column Area: 192.00 in
 Rebar Size: 5
 Bar Count Each Face: 4
 ...rebar area: 1.240 in²
 Rebar Depth: 9.875 in
 fm: 1,500.0 psi
 Fs: 24,000.0 psi
 Em = fm * : 750.0
 Special Inspection:
 94 UBC Seismic Factor Z Ip Cp: 0.000
 Seismic Zone: 0
 Density: 125.00 pcf
 Load Duration Factor: 1.330

Results | Sketch | Printing

Summary | Design Values

Column Design OK

Max. Bending + Axial Comp. Stress	348.12 psi
Allowable	500.00 OK
Max. Axial Only Compressive Stress	81.48 psi
Allowable	528.66 OK
Max Steel Bending Stress	8,973.82 psi
Allowable	24,000.00 OK

Summary...

Vertical Loads...

Total @ Top	Dead	7.25 k
	Live	4.55 k
Total @ Mid-Ht	Dead	6.50 k
	Live	4.55 k

Lateral Loads...

Wind + Lateral	65.00 #/ft
Seismic + Lateral	0.00 #/ft

Combined Moments...

Top DL + LL	5,900.00 ft-#
Mid: DL + LL + Wind	3,454.47 ft-#
Mid: DL + LL + Seismic	3,625.00 ft-#

Basic Usage

- The Design Data section is used to define material strengths, special inspection status, seismic and wind factors, and column weights. These values allow you to design a variety of column types subjected to lateral and vertical loads.
- Loading Data defines the girder load and eccentricity applied to the top of the column. In addition, you may apply an Additional Lateral Load acting over all or a portion of the column. This is in addition to the automatically applied wind and column weight seismic loads.
- The Column Data section is where you specify column height, dimensions, and reinforcing. You will continuously modify these values while recalculating to generate

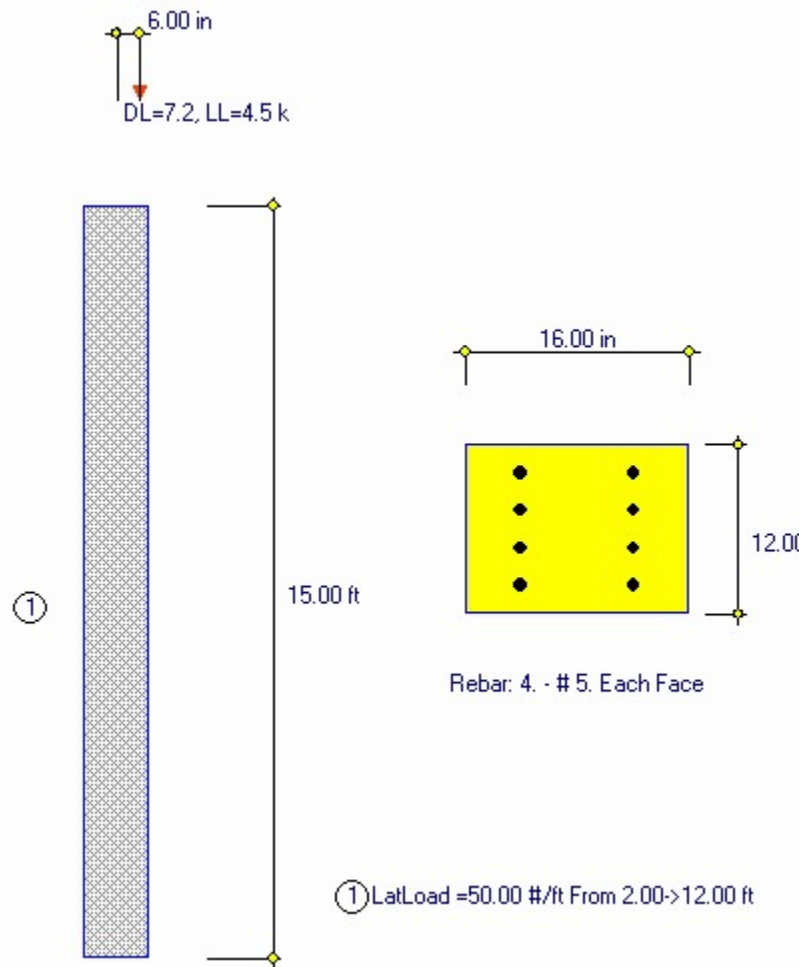
an acceptable design.

Unique Features

- This program permits quick and easy evaluation of a masonry column subjected to a variety of forces, with varying materials and reinforcing.
- Both wind and seismic analysis is performed with each recalculation.
- The column can easily be checked for support of tributary lateral loads from an attached wall, when the wall spans between columns and the columns are used to transfer load to top and bottom boundary elements.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams,

etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General		Loads	
Description		Column w/ additional later load : 2' -> 12'	
Column Height	15.000	ft	
Column Width	12.000	in	
Column Depth	16.000	in	
Column Area	192.00	in	
Rebar Size	5		
Bar Count Each Face	4		
...rebar area	1.240	in ²	
Rebar Depth	12.000	in	
fm	1,500.0	psi	
Fs	24,000.0	psi	
Em = fm *	750.0		
Special Inspection	<input checked="" type="checkbox"/>		
'94 UBC Seismic Factor Z Ip Cp . . .	0.000		
Seismic Zone	0		
Density	125.00	pcf	
Load Duration Factor	1.330		

Column Height

The effective height is measured from the point of lateral support at the floor to point of lateral support at the roof. This distance is used to determine all moments in the wall by simple span between floor and roof. If the column has no top lateral support ("cantilevered"), this height should already be adjusted by the typical column "K" factor.

Column Width

Enter the column width measured parallel to the bending axis.

Column Depth

This is the depth (strong axis) of the column, measured perpendicular to the axis of bending.

Gross Column Area

Gross column area equals the (depth - 5/8") * (width - 5/8").

Rebar Size #

Enter rebar size to be used at each face.

Bar Count Each Face

Enter number of bars considered effective at each face of the column.

Rebar Depth

Enter the effective reinforcing depth to be used for calculation of bending capacity of the column. This value will automatically be internally limited to (Nominal Depth - 0.625" - 1.5")

f'm

Enter the allowable masonry strength to be used in the analysis. The allowable bending and axial stresses calculated from F'm are outlined in a later section. If the user has chosen not to use special inspection, both allowable axial and bending stresses will be multiplied by 1/2.

Fs

Enter the allowable tension strength of the reinforcing to be used. This value will be used as entered to determine the interaction equations for the design being performed.

Em = f'm * Multiplier

This value is multiplied by f'm to calculate the modulus of elasticity for masonry. You may enter different values here to have the Em and subsequent n values altered.

Special Inspection

In this location, specify 1" if special inspection will be used, allowing full f'm based masonry stresses to be used. Entering "0" specifies that no special inspection will be performed, and all allowable stresses will be reduced by 1/2.

'94 UBC Seismic Factor

Enter the seismic factor to be applied to the wall/column weight when calculating the lateral moment. This value is usually the result of the UBC formula "ZICp".

Seismic Zone

Enter the UBC Seismic Zone.

Column Unit Density

You may enter the unit weight of the column material. The exact unit weight may be specified here, depending on use of light, medium, or normal weight block/grout, or weights gathered from test reports.

Load Duration Factor

This entry is used as the maximum interaction value that all load combinations that include wind or seismic load must be less than or equal to.

Loads Tab

General		Loads	
Wind Load		<input type="text" value="15.000"/>	psf
Vertical Load			
Dead Load		<input type="text" value="7.250"/>	k
Live Load		<input type="text" value="4.550"/>	k
Eccentricity		<input type="text" value="6.000"/>	in
Load Type		<input checked="" type="radio"/> Roof	<input type="radio"/> Floor
Lateral Load		<input type="text" value="50.000"/>	#/ft
Distance to bottom		<input type="text" value="2.000"/>	ft
Distance to top		<input type="text" value="12.000"/>	ft
Load Type		<input checked="" type="radio"/> Wind	<input type="radio"/> Seismic

Wind Load

Enter the wind load acting on the column width. The moment created from this load will be combined with eccentric girder load moment to determine the final lateral wind moment.

Vertical Dead & Live Load

The user specifies an axial dead and live load applied at the top of the column. This load is used to determine the concentrated moment at the top of the column (and decreases linearly to zero at the bottom of the column).

Load Eccentricity

The user can specify that the girder load is applied to the column at an eccentricity. When determining maximum moments, the moment created by the girder load is always added to the lateral load moments, regardless of whether eccentricity is positive or negative. This load is included in both bending and axial load computations.

Load Type

This indicates whether the vertical load is a floor or roof load. This distinction is important because only floor loads are added to seismic or wind loads for the analysis.

Lateral Loads

Applied laterally to the column to create simple bending moments. This load will be applied to the column as is (no further load factoring will be performed), and is in addition to the wind or seismic load.

Top & Bottom Distances

These two entries define the starting and ending point of the load with respect to the bottom of the column.

Load Type

This flag instructs the program how to include the additional uniform load into the lateral loads (whether into wind or seismic load cases).

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results / Summary Tab

Results		Sketch	Printing
Summary		Design Values	
Max. Bending + Axial Comp. Stress	264.58	psi	
Allowable	500.00		OK
Max. Axial Only Compressive Stress	61.48	psi	
Allowable	529.68		OK
Max Steel Bending Stress	5,665.09	psi	
Allowable	24,000.00		OK
Summary...			
Vertical Loads...			
Total @ Top	Dead	7.25	k
	Live	4.55	k
Total @ Mid-Ht	Dead	8.50	k
	Live	4.55	k
Lateral Loads...			
Wind + Lateral		65.00	#/ft
Seismic + Lateral		0.00	#/ft
Combined Moments...			
Top DL + LL		5,900.00	ft-#
Mid: DL + LL + Wind		3,454.47	ft-#
Mid: DL + LL + Seismic		3,625.00	ft-#

Final Results

At the top of this tab are the final maximum values and their comparable allowables.

Summary

This area summarizes the calculated vertical loads, lateral loads, and moments that are used for the stress analysis.

Results / Design Values Tab

Results Sketch Printing						
Summary Design Values						
Top of Column			<u>Bending Stresses</u>		<u>Axial Stress</u>	
	<u>Moment</u>	<u>Axial</u>	<u>Steel</u>	<u>Masonry</u>		
	ft-#	lbs	psi	psi	psi	
DL+LL	5,900.0	11,800.0	5,665.1	203.12	61.46	
Btwn Base & Top of Column						
DL+LL+W	3,454.5	8,500.0	3,316.9	118.93	44.27	
DL+LL+S	3,625.0	8,500.0	3,480.7	124.80	44.27	
Allowable Steel Tension			24,000.00 psi			
Fa: $[.25 * f_m * A_{eff} * (.5 \text{ w/o sp. insp.}) * (.5 \text{ if thk} < 12") + .65 * a_s * F_{sc}] * [1 - (h/140r)^2]$			529.66 psi			
Fb: Masonry: $0.33 * f_m * (.5 \text{ w/o sp. insp.}) \leq 2000$			500.00 psi			
Max Allow Moment w/o Axial Load			14,377.89 ft-#			
Max. Allow Axial Load w/o Moment			101.69 k			
E			1,125,000 psi			
Radius of Gyration			4.511 in			
np			0.22198			
k			0.48032			
j			0.83989			
2/kj			4.95761			
n			25.778			

Top of Column

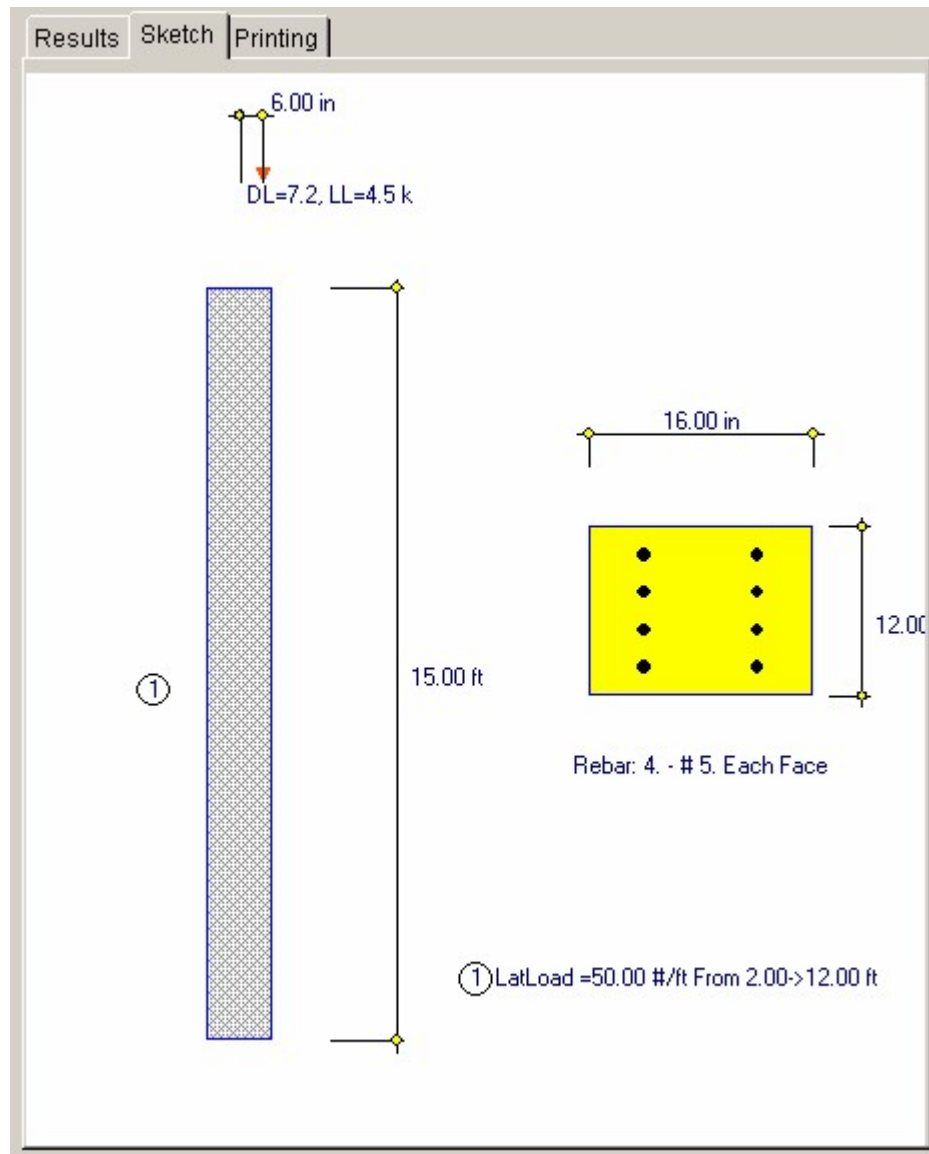
This area displays the calculated moment, axial load, and stresses at the to of the column. The moments are the result of axial load eccentricity.

Between Base and Top Of Column

This area summarizes the calculated moment, axial loads, and stresses when two different load combinations are used to calculate moments between the top and bottom of the wall (simply span beam moments) due to axial load eccentricity and lateral loads.

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Applied Loads	<input checked="" type="checkbox"/>
Design Values	<input checked="" type="checkbox"/>
Load Combination & Stress Details Summary	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Summary of Loads & Moments	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 6:06PM, 28 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Description Column w/ additional later load : 2' -> 12'

General Information Code Ref. ACI 530-02

Column Height	15.000 ft	f'm	1,500.00 psi	Seismic Factor	0.0000
Width	12.000 in	Fs	24,000.00 psi	Seismic Zone	0
Depth	16.000 in	Em = f'm*	750.0	Wall Density	125.000 pcf
Column Area	192.00 in2			Load Duration Factor	1.330
Rebar Size	5			Special Inspection	
Bar Count Each Face	4				
...rebar area	1.240 in2				
Rebar Depth	9.875 in				

Applied Loads

Vertical Load		Lateral Load	50.00 #/ft
Dead Load	10.00 k	... distance to bottom	2.000 ft
Live Load	10.00 k	... distance to top	12.000 ft
eccentricity	6.000 in	Load Type	Wind
Load Type	Roof	Wind Load	15.00 psf

Design Values

Allowable Steel Tension	24,000.00 psi	np	0.26974	j	0.82909
Fa: [.25*f'm*Aseff*(.5 w/o sp. insp.)* (.5 if thk < 12") + .65*as*Fsc] * [1-(h/140r)^2]	529.66 psi	k	0.51272	2/kj	4.70486
Fb: Masonry: 0.33*f'm*(.5 w/o sp. insp) <= 2000	500.00 psi	E		n	25.778
Max Allow Moment w/o Axial Load	10,259.64 ft-#				
Max. Allow Axial Load w/o Moment	101.69 k				1,125,000 psi in

Load Combinations & Stress Details Summary

	Moment ft-#	Axial lbs	Bending Stresses		Axial Stress psi
			Steel psi	Masonry psi	
Top of Wall					
Dead + Live Load	10,000.0	20,000.0	11,820.0	482.47	104.17
BTwn Base & Top of Wall					
Dead + Live + Wind	4,132.8	11,250.0	4,885.0	199.40	58.59
Dead + Live + Seismic	5,000.0	11,250.0	5,910.0	241.24	58.59

Summary **Pilaster Overstressed**

15ft high column, Width= 12.000in, Depth= 16.000in Using 4 - #5 bars at 'd' = 9.88in

Max. Bending + Axial Comp. Stress	586.64 psi
Allowable	500.00 N.G
Max. Axial Only Compressive Stress	104.17 psi
Allowable	529.66 OK
Max Steel Bending Stress	11,820.04 psi
Allowable	24,000.00 OK

ENERCALC Engineering Software
P.O. Box 188
Corona del Mar, CA 92660
Voice: 949-645-0151
www.enercalc.com

Title : ENERCALC Example Problems **Job #** 97-000001
Dsgnr: MDB **Date:** 6:06PM, 28 OCT 03
Description : Collection of example problems
Scope : All programs in the Structural Engineering Library

Rev: 590000
 User: KVA-0000001, Ver: 5.8.0, 10-Sep-2003
 (c)1983-2003 ENERCALC Engineering Software **Masonry Column Design** Page 2
 c:\ec59\examples.ecw\Masonry Gates

Description Column w/ additional later load : 2' -> 12'

Summary of Loads & Moments

Vertical Loads...			Lateral Loads...	
Total DL @ Top	10.00 k	10.00 k	Wind + Lateral	65.00 #/ft
Mid-Height DL + LL	11.25 k	10.00 k	Seismic + Lateral	0.00 #/ft
Combined Moments...				
Top DL + LL	10,000.00 ft-#			
Mid: DL + LL + Wind	4,132.80 ft-#			
Mid: DL + LL + Seismic	5,000.00 ft-#			

3.4 Flush Wall Pilaster

This program provides design and analysis of columns contained entirely within the thickness of a masonry wall. The column may be subjected to a combination of eccentric vertical loads and lateral loads due to seismic or wind forces.

Loading conditions include a dead and live girder load applied to a bearing seat, dead and live uniform load applied eccentrically to the top of the wall, and lateral loads due to wind and seismic forces.

The user may specify allowable masonry and steel stresses, status of special inspection, status of solid grouting, seismic factor, wind load, and bearing plate dimensions, wall

thickness, rebar size and spacing, rebar location, and wall span data.

All axial load and bending moment stresses are calculated and combined using the interaction equation. Combined stresses at the top of the pilaster and at mid-height are checked.

Flush Wall Masonry Pilaster

Tools & Settings | ? Help | Print | Cancel | Save

General | Material | Applied Loads | Results | Sketch | Printing

Description: Wall section taking girder loads & uniform ecc loads

Pilaster Height: 12.000 ft
 Thickness: 8.00 in
 Rebar Size: 6
 Rebar Spacing: 8.000 in
 Rebar Location: Center Edge
 Block Type: Light Medium Normal
 Bearing Plate Width: 15.000 in
 Column Width: in (Set = 0 for auto-calc of width)
 Aplate < (33*Atof):
 Column Width used: 34.105 in
 94 UBC Seismic Factor Z Ip Cp: 0.300
 Seismic Zone: 0
 Solid Grouted:
 Load Duration Factor: 1.330

Summary | Design Values | Load Summary

Max. Bending + Axial Comp. Stress: 96.71 psi
 Allowable: 247.50 OK
 Max. Axial Only Compressive Stress: 35.05 psi
 Allowable: 183.49 OK
 Max Steel Bending Stress: 2,152.01 psi
 Allowable: 28,800.00 OK

	Top of Pilaster	Btwn Base & Top of Pilaster	
	DL+LL	DL+LL+Wind	DL+LL+Seismic
Moment	1,026.94	1,187.86	1,464.12 ft-#
Axial Load	9,085.26	5,968.53	5,968.53 lbs
Bending Stresses			
Steel	1,508.43	1,745.96	2,152.01 psi
Masonry	61.65	71.32	87.91 psi
Axial Stress	35.05	23.03	23.03 psi
Required Bearing Area	31.58in ²		
Req'd Bearing Length	2.11in		

Basic Usage

- In the section titled Design Data, enter the material strengths and inspection status for the wall. Seismic Factor and Wind Load are both used to generate lateral loads applied to the wall. The resulting moments are detailed in the Summary section. You must also enter a Bearing Plate Length to be used to spread the applied vertical load out over an effective width of the pilaster.
- The Loading Data section allows you to apply eccentric vertical uniform roof or floor loads and a concentrated girder load. You can use either or both of these entries to apply vertical load to the pilaster.
- Pilaster Data defines the clear span, thickness, and reinforcing for the flush wall pilaster. You typically modify these three values while recalculating to reach the final pilaster design. You can place the rebar at the Center or Edge of the wall.
- The above entries are all that is required to completely specify a wall section. Calculating the program will perform the analysis for maximum bending and axial stresses. The analysis always produces results for both wind and seismic load cases.

- You can then proceed to Check Actual And Allowable Moments, deflection ratios, reinforcing percentages, and axial stress levels. If any are not within limits, you can modify reinforcing or wall thickness to bring the actual values into compliance.
- When finished, Print or Save the data for the current calculation, Reset all the program values to zero for a new problem, or use the Access Menu to use another program.

Unique Features

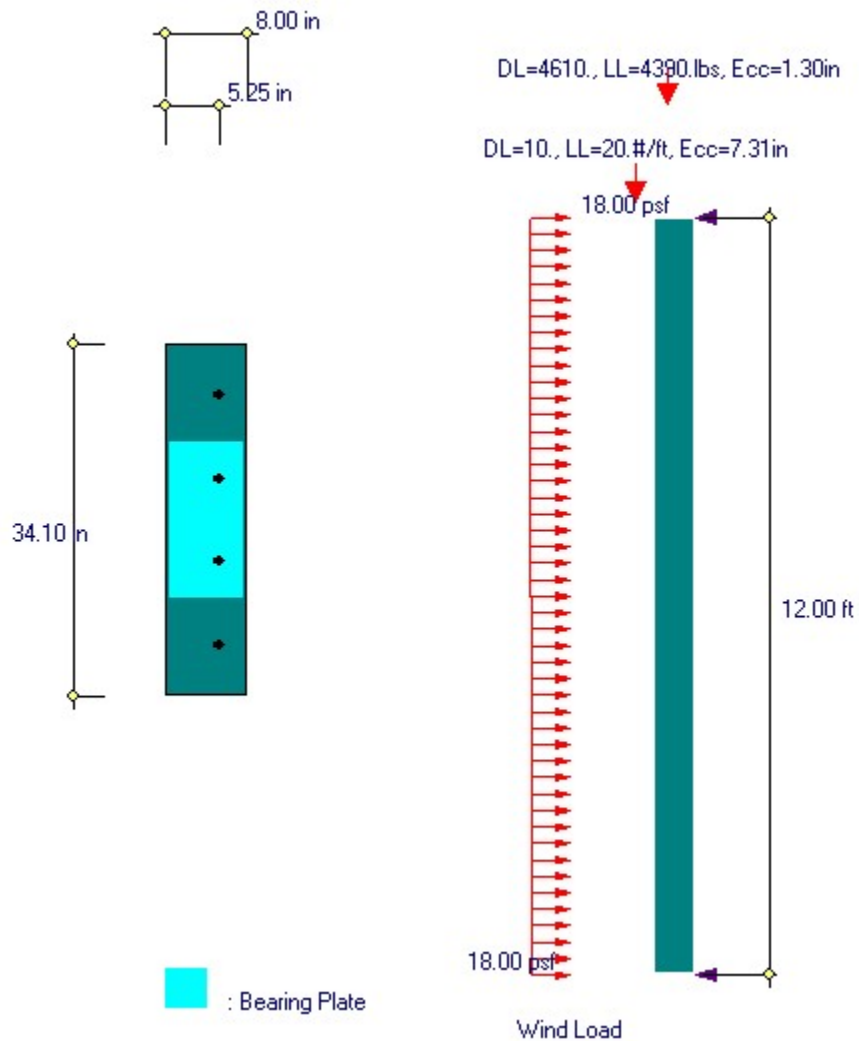
- This program permits quick evaluation of a flush wall pilaster subjected to a variety of forces, with varying materials and reinforcing.
- Both seismic and wind analysis is provided.
- Detailed bending and axial stress results are supplied for various load combinations at the top of the column and mid-height.

Assumptions & Limitations

- P-Delta effects are not considered. The conventional formulas for evaluating allowable axial and bending stresses in masonry are used, based on the U.B.C. and similar codes.
- Girder loads and uniform vertical loads are both applied to the pilaster at the same elevation.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General	Material	Applied Loads
Description Wall section taking girder loads & uniform ecc loads		
Pilaster Height	12.000	ft
Thickness	8.00	in
Rebar Size	6	
Rebar Spacing	8.000	in
Rebar Location	<input type="radio"/> Center <input checked="" type="radio"/> Edge	
Block Type	<input type="radio"/> Light <input checked="" type="radio"/> Medium <input type="radio"/> Normal	
Bearing Plate Width	15.000	in
Column Width		in (Set = 0 for auto-calc of width)
Aplate < (.33*Atot)	<input checked="" type="checkbox"/>	
Column Width used	34.105	in
94 UBC Seismic Factor Z Ip Cp	0.300	
Seismic Zone	0	
Solid Grouted	<input checked="" type="checkbox"/>	
Load Duration Factor	1.330	

Pilaster Height

The effective height is measured from the points of lateral support at the floor and roof/second floor. This distance is used to determine moments in the wall due to applied lateral seismic and wind loads. For flush-wall columns in walls with no top support, use this entry to specify the effective column height (height adjusted by K factor for columns).

Wall Thickness

Enter the nominal wall thickness you are using or estimate what will be needed. A table of d values, equivalent solid thicknesses, and weights are stored in the program, and the appropriate value will be selected based upon nominal wall thickness. Thickness values of 6", 8", 10", 12", 14", and 16" are allowed.

Rebar Size

The user enters choice of rebar to be used in the analysis (#14 & #18 bars will be ignored).

Rebar Spacing

The rebar spacing entered here applies to the rebar size entered above. Please be sure to enter the

spacing as it applies to the block modules being used! Rebar spacings of 8", 16", 24", 32", 40", and 48" are allowed.

Rebar Location

Enter a 0" if the vertical reinforcement will be located at the centerline of the wall, or a 1" if it will be located at the outside edge. NOTE: If reinforcing is stated to be at each face, the compression face reinforcing will not be used in the evaluation of bending capacity (only one bar at the d distance for bar placed at each face will be used).

Block Type

This entry controls what block type is being used for determining the wall weight to be recalled from the internal tables. Select Lightweight, Medium Weight, or Normal Weight.

Bearing Plate Width

This represents the width of the bearing plate (measured perpendicular to the wall) which the girder will rest upon. From this width, the required Bearing Length will be calculated, thus determining the b for the assumed pilaster width.

Bearing Plate Width**Is Plate Area < (Total Area / 3) ?****Column Width Used**

This is the assumed total width of the flush wall pilaster to be used for the balance of the design. It is equal to length of bearing plus four times the wall thickness. If desired, the user can enter another value here, in such cases where a narrower pilaster width is required.

Seismic Factor

Enter the seismic factor to be applied to the wall/pilaster weight when calculating the lateral moment.

Seismic Zone

Enter the UBC Seismic Zone

Solid Grouted

Check this box if the wall is solid grouted. Otherwise it is assumed that grouting is at cells with reinforcing only.

This entry is used as the maximum interaction value that all load combinations (that include wind or seismic load) must be less than or equal to.

Material Tab

Parameter	Value	Unit
f_m	1,500.0	psi
F_s	20,000.0	psi
$E_m = f_m *$	750.0	
Wall Weight Multiplier	1.000	
E	1125,000.0	
n	25.778	
Special Inspection	<input type="checkbox"/>	

 f_m

Enter the allowable masonry strength to be used in the analysis. The allowable bending and axial stresses calculated from F_m are outlined in a later section. If the user has chosen to use $\frac{1}{2}$ stresses, both allowable axial and bending stresses will be multiplied by $\frac{1}{2}$.

 F_s

Enter the allowable tension strength of the reinforcing to be used. This value will be used as entered to determine the interaction equations for the design being performed.

"n" Multiplier

This value is multiplied by f_m to calculate the modulus of elasticity for masonry. You may enter different values here to have the E_m and subsequently n values altered.

 E_m

The modulus of elasticity used is calculated as n Multiplier * f_m . If special inspection is not used, E_m is not reduced by $\frac{1}{2}$.

n: E_s/E_m

This is the ratio of steel modulus E_s (29×10^6) divided by E_m as calculated above.

Special Inspection

Check the box to specify that Special Inspection will be used, therefore allowing full F_m based masonry stresses to be used, otherwise a multiplier of $\frac{1}{2}$ will be applied to F_m based allowable stresses.

Applied Loads Tab

General	Material	Applied Loads
Uniform Loads		
Dead Load	<input type="text" value="10.00"/>	#/ft
Live Load	<input type="text" value="20.00"/>	#/ft
...eccentricity	<input type="text" value="7.310"/>	in
Load Type	<input checked="" type="radio"/> Roof <input type="radio"/> Floor	
Girder Load		
Dead Load	<input type="text" value="4,610.00"/>	lbs
Live Load	<input type="text" value="4,390.00"/>	lbs
...eccentricity	<input type="text" value="1.300"/>	in
Load Type	<input checked="" type="radio"/> Roof <input type="radio"/> Floor	
Wind Load . . .	<input type="text" value="18.000"/>	psf

Uniform Loads

Uniform loads can be applied to the effective width of the flush wall pilaster at the specified eccentricity. The program resolves this loading to an axial load and concentrated moment applied at the location of Clear Span Height. The concentrated moment is assumed to decrease to zero at the lower lateral support, and is included in both bending and axial load computations

Uniform Load Eccentricity

The user may specify that the uniform loads are applied at an eccentricity to the pilaster centerline. When determining maximum moments, the moment created by the uniform load is always ADDED to the lateral load moments, REGARDLESS OF WHETHER ECCENTRICITY IS POSITIVE OR NEGATIVE.

Girder Loads

You can also specify an axial load applied to the top of the column. This load is used to determine concentrated moment at the top of the column, $\frac{1}{2}$ of which is considered effective at mid-height. This load is applied to the pilaster via the Bearing Plate, whose length determines the effective length of the pilaster.

Girder Load Eccentricity

The user can specify that the girder load is applied to the column at an eccentricity. When determining maximum moments, the moment created by the girder load is always added to the lateral load moments, regardless whether eccentricity is positive or negative. This load is included in both bending and axial load computations.

Wind Load

Enter the wind load acting on the Pilaster Width. The moment created from this load will be combined with eccentric girder load moment to determine the final mid-height moment.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results / Summary Tab

Results		Sketch	Printing
Summary		Design Values	Load Summary
Max. Bending + Axial Comp. Stress	96.71	psi	
Allowable	247.50		OK
Max. Axial Only Compressive Stress	35.05	psi	
Allowable	183.49		OK
Max Steel Bending Stress	2,152.01	psi	
Allowable	26,600.00		OK
	<u>Top of Pilaster</u>	<u>Btwn Base & Top of Pilaster</u>	
	<u>DL + LL</u>	<u>DL+LL+Wind</u>	<u>DL+LL+Seismic</u>
Moment	1,026.94	1,187.86	1,464.12 ft-#
Axial Load	9,085.26	5,968.53	5,968.53 lbs
Bending Stresses			
Steel	1,509.43	1,745.96	2,152.01 psi
Masonry	61.66	71.32	87.91 psi
Axial Stress	35.05	23.03	23.03 psi
Required Bearing Area		31.58in ²	
Req'd Bearing Length		2.11in	

Results / Design Values Tab

Results Sketch Printing	
Summary Design Values Load Summary	
Allow Brg. Stress	285.00 psi
Allow Axial Stress	183.49 psi
Reduction Factor	0.782
Allow Masonry Bending Stress	247.50 psi
Max. Allow Moment w/o Axial Load	4,122.08 ft-#
Max. Axial Load w/o Moment	47,561.49 ft-#
Rebar Area	1.876 in ²
Rebar Depth	5.250 in
Equivalent Solid Thickness	7.600 in
Moment of Inertia	443.32 in ⁴
Radius of Gyration	2.20 in
np	0.2701
j	0.8290
k	0.5129
2/kj	4.7035
Pilaster Weight	78.000 psf

Allowable Bearing Stress

The allowable bearing stress under the girder bearing plate, based on f_m and $APLATE \leq 0.33$

Allow Axial Stress

This is equal to: $.26 * f_m * (.5 \text{ w/o sp. insp.})$ when the plate area is greater than $1/3 \text{ ATOT}$ and $0.38 * f_m * (.5 \text{ w/o sp. insp.})$ when the plate area is less than $1/3 \text{ ATOT}$.

Reduction Factor

Equals : $(1 - (h/42t)^3)$

Allowable Masonry Bending Stresses

Equals the code specified allowable compressive stress in bending for masonry.

$$f_b = .333 f_m * (.5 \text{ w/o sp. insp.}) \leq 2,000.$$

Max. Allow. Moment w/o Axial

This equals the maximum moment capacity of the wall section if no axial load acted to reduce the capacity.

Max. Allow. Axial w/o Moment

This equals the maximum axial capacity of the wall section if no bending load acted to reduce the capacity.

Rebar Area

Based upon the specified rebar size number and spacing, the equivalent rebar area per foot of wall length is given. Rebar area is recalled from an internal table.

Rebar Depth

From the selected wall thickness and center or edge location, the appropriate d is selected from an internally stored table.

Equivalent Solid Thickness

Using the wall thickness and rebar spacing and solid grouting selection the equivalent thickness of the wall is given which takes into account the void spaces. For a solid grouted wall the result would be the actual wall thickness.

Moment of Inertia, Radius of Gyration, n_p , j , k , $2.k_j$

Calculated values of the wall used for stability and allowable axial stress calculations.

Pilaster Weight

The wall weight is automatically recalled from an internal table of weights, considering rebar spacing, wall thickness, and status of solid grouting. The table is based on normal weight block, not lightweight or medium weight.

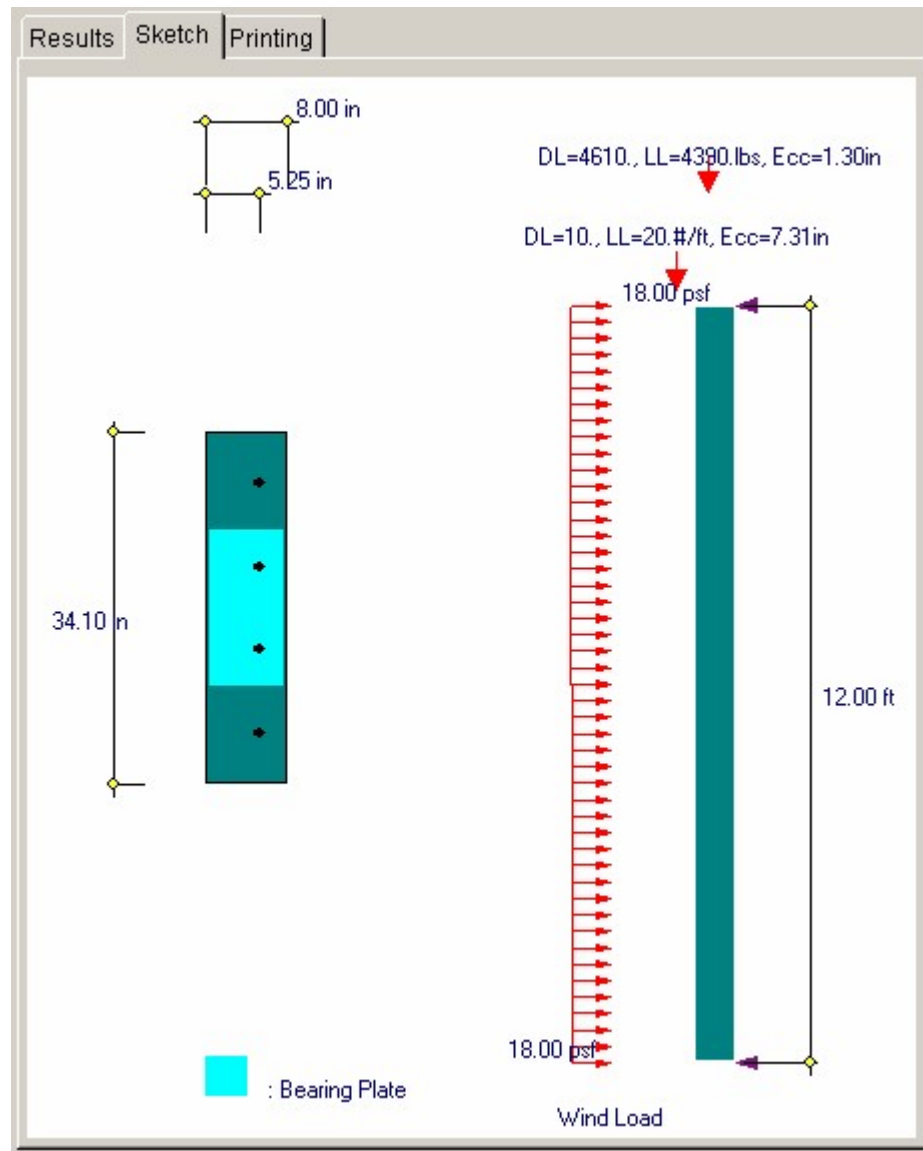
Results / Load Summary Tab

This tab summarizes the axial loads and moments that have been calculated for the critical sections of the wall where maximum design stresses are evaluated.

Results Sketch Printing		
Summary Design Values Load Summary		
Girder + Uniform Dead Loads		4,638.42 lbs
Girder + Uniform Live Loads		4,446.84 lbs
Pilastr Weight @ Mid-Height		1,330.11 lbs
	@ TOW	@ Mid-Ht
Girder DL Moments	499.4	249.7
Girder LL Moments	475.6	237.8
DL Moments @ mid-height		8.66 ft-#
LL Moments @ mid-height		17.31 ft-#
Wind Moment @ Mid-Ht		920.84 ft-#
Seismic Moment @ Mid-Ht		1,197.09 ft-#

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Applied Loads	<input checked="" type="checkbox"/>
Design Values	<input checked="" type="checkbox"/>
Load Combinations & Stress Details	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Summary of Loads & Moments	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 7:07PM, 28 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 680000
 User: RW-0500001, Ver 6.0.0, 10-Sep-2003
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Masonry Flush Wall Pilaster/Column Page 1
 c:\2003\exam\pe\c\2003

Description Wall section taking girder loads & uniform ecc loads

General Information Code Ref: ACI 530-02

Wall Height	12.000 ft	Block Type	Medium Wt	f _m	1,500.0 psi
Thickness	8 in	Bearing Plate Width	5.000 in	F _s	20,000.0 psi
Rebar Size	6	Column Width	48.000 in	E _m = f _m *	750.0
Rebar Spacing	8.000 in	A _{plate} < (.33*A _{col})		No Special Inspection	
Rebar Location	Center	Column Width used	48.000 in	Solid Grouted	
Seismic Factor	0.300	Load Duration Factor	1.330	E	1125,000.0 psi
Seismic Zone	0	Wall Wt Multiplier	1.000	n	25,778

Applied Loads

Uniform Loads		Girder Load	
Dead Load	10.00 #/ft	Dead Load	4,610.00 lbs
Live Load	20.00 #/ft	Live Load	4,390.00 lbs
...eccentricity	7.310 in	...eccentricity	1.300 in
...load Type	Roof	...load Type	Roof
Wind Load	18.00 psf		

Design Values

AllowBrg. Stress	285.00 psi	Rebar Area	2.640 in ²
AllowAxial Stress	183.49 psi	Rebar Depth	3.610 in
Reduction Factor	0.78	Wall Weight	78.000 psf
AllowMasonry Bending	247.50 psi	np	0.3721
Max. AllowMoment w/o Axial Load	3,305.97 ft-#	i	0.8109
Max. Axial Load w/o Moment	66,938.39 lbs	Radius of Gyration	2.205 in
		Moment of Inertia	443.320 in ⁴

Load Combinations & Stress Details

	Moment	Axial	Steel	Masonry	Axial Stress
Top of Wall					
DL + LL	1,048.10	9,120.0	1,542.08	78.47	25.00
Botwn. Base & Top of Wall					
DL + LL + Wind	1,570.07	6,522.0	2,310.07	117.54	17.88
DL + LL + Seismic	1,958.87	6,522.0	2,882.11	146.65	17.88
Required Bearing Area	31.58 in ²				
		Req'd Bearing Length			6.32 in

Summary Pilaster Design OK

12.00ft high, 8.00in thick w/ #6 @ 8.00in o.c. at center, No Special Inspection, Solid Grouted

Max. Bending + Axial Comp. Stress	164.53 psi
Allowable	329.18 OK
Max. Axial Only Compressive Stress	25.00 psi
Allowable	183.49 OK
Max Steel Bending Stress	2,882.11 psi
Allowable	26,600.00 OK

Summary of Loads & Moments

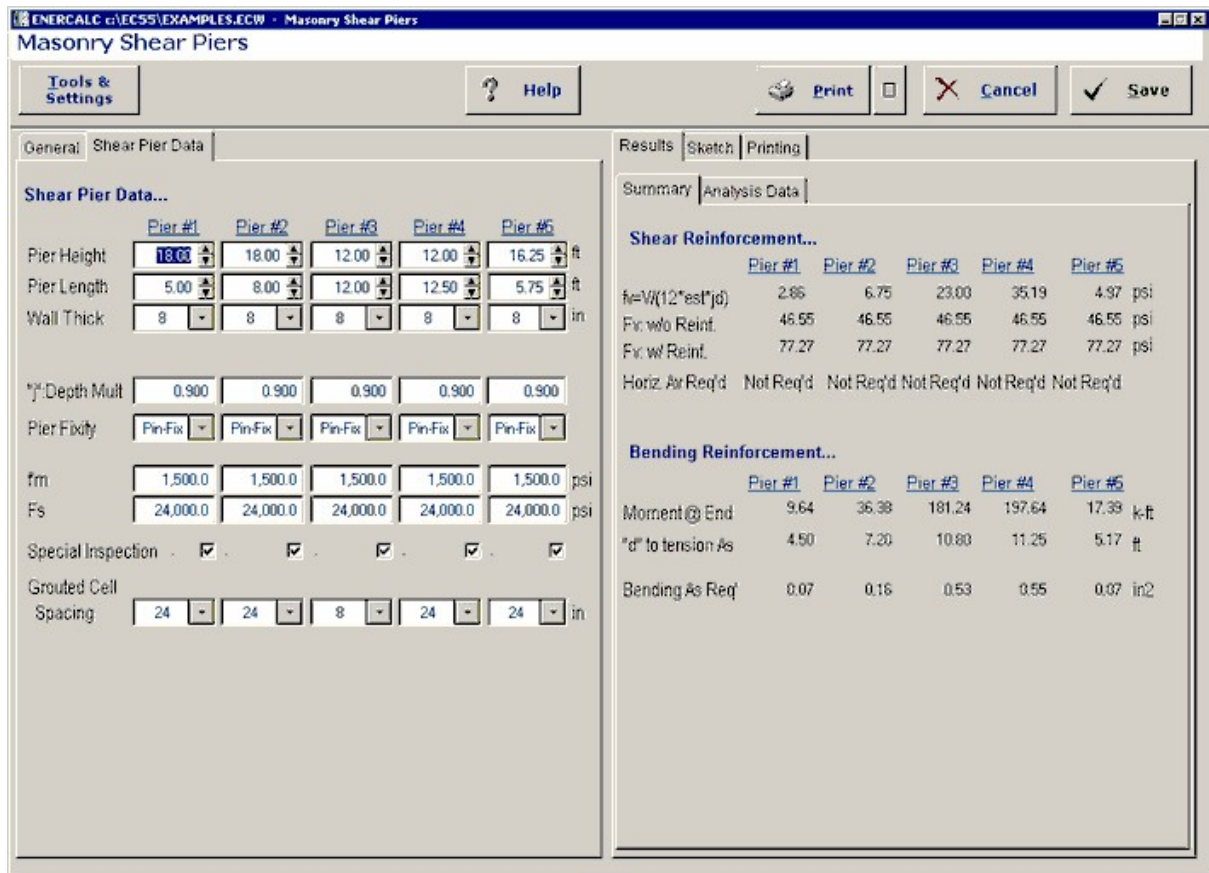
Girder + Uniform Dead Loads	4,650.00 lbs		@ TOW	@ Mid-Ht
Girder + Uniform Live Loads	4,470.00 lbs	Girder DL Moments	499.4	249.7 ft-#
Wall Weight @ mid-height	1,872.00 lbs	Girder LL Moments	475.6	237.8 ft-#
DL Moments @ mid-height	12.18 ft-#	Wind Moment @ Mid-Ht		1,296.00 ft-#
LL Moments @ mid-height	24.37 ft-#	Seismic Moment @ Mid-Ht		1,684.80 ft-#

3.5 Shear Piers

This program provides design and analysis ability for masonry shear wall sections subject to in-plane lateral loads (parallel to their length). You can model a series of shear pier segments that will each carry a percentage of an applied lateral force based upon the relative rigidities of each segment.

A maximum of five shear piers may be specified, each with its own length, height, thickness, and fixity conditions. Also, each of these piers may have individual allowable stresses for conditions where higher strengths are required for specialized designs of highly stressed sections. A load duration factor can be entered for stress adjustments when the nature of loading changes.

The program automatically determines individual pier stiffness's and distributes an overall single applied lateral load to each pier. Unit shear forces, design shear forces, and bending moments in each pier are calculated and used to determine the required shear and end reinforcing.



Basic Usage

- First, enter the Total Lateral Load to be applied to the group of shear piers, including the load contributed by the wall. This load will be distributed to each pier

in proportion to their relative rigidities. The Load Duration Factor is used to modify the allowable stresses.

- The Design Data section provides all data entries for the group of piers. Pier Height, Length, and Thickness define the pier dimensions to be used for rigidity calculation and stress/reinforcing evaluation. The "j" entry is used to design the wall's stress block depth, used to calculate shear and bending depths. Fixity Code defines the end restraint condition of the wall and effects the rigidity calculations. You can also specify Special Inspection and Grouted Cell Spacing, both of which will effect the allowable stresses for both shear and bending.
- After all data has been entered, calculate the program and review the interaction values in the Summary section. You will notice that all stress components for all load combinations and locations are listed for your review. Continue to modify the Design Data and recalculate until all interaction values are below acceptable levels.

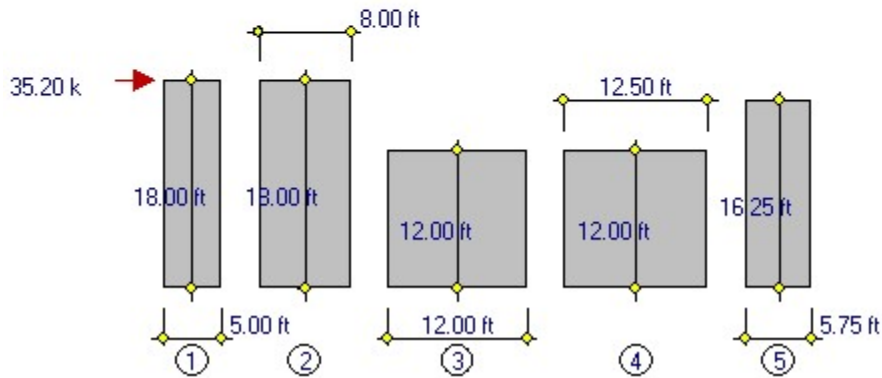
Unique Features

- This program reduces the tedious hand calculation process of determining rigidities, calculating stresses, and then performing the whole operation over again with each refinement.
- In addition to determining forces by relative rigidities, the program determines actual and allowable shear stresses, and provides the required minimum reinforcement area as needed.
- Assumptions & Limitations
- Because of the complexity in determining the rigidity of a wall system, this program idealizes the pier system by assuming that the wall sections providing Fixity are infinitely rigid, and do not deflect in such a manner as to alter the rigidity of adjacent piers.
- All piers are assumed to act in-line. A complex analysis of shear blocks and combined effects of openings & shear blocks is not performed.
- Self-weight of the wall is not automatically included for seismic in plane load, and must be included in the total applied load.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.

- ① 8.0 in Thick, Pin-Fix, Cells grouted at 24. in, Pier Load = 0.53 k
- ② 8.0 in Thick, Pin-Fix, Cells grouted at 24. in, Pier Load = 2.02 k
- ③ 8.0 in Thick, Pin-Fix, Cells grouted at 8. in, Pier Load = 15.10 k
- ④ 8.0 in Thick, Pin-Fix, Cells grouted at 24. in, Pier Load = 16.47 k
- ④ 8.0 in Thick, Pin-Fix, Cells grouted at 24. in, Pier Load = 1.07 k



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General	Shear Pier Data
Description	Four pier assembly, varying lengths
Total Lateral Force	35.20 k
Seismic Zone	4
Load Duration Factor	1.330
Moduli: $E_m = f_m *$	750.0
Use Grouting at Face Shells Only ?	<input type="checkbox"/>

Total Lateral Force

Enter the total lateral force, acting parallel to the piers, which will be distributed to each pier. Distribution is by relative rigidities.

Seismic Zone

Enter the UBC Seismic Zone.

Load Duration Factor

This factor will be applied to the f'_m and F_s values to give the allowables to be used in the analysis.

Moduli: $E_m = f'_m * (\text{entry})$

In masonry construction the value of E_m (Elastic Modulus of the masonry) is calculated as a multiplier applied to f'_m . Enter that multiplier here.

Use Grouting at Face Shells Only?

This item tells the program whether to calculate equivalent solid thickness using just the face cells with grout in the bedding or that all block surfaces that mate with the next block above or below have a grout bed.

Shear Pier Data Tab

	Pier #1	Pier #2	Pier #3	Pier #4	Pier #5	
Pier Height	18.00	18.00	12.00	12.00	16.25	ft
Pier Length	5.00	8.00	12.00	12.50	5.75	ft
Wall Thick	8	8	8	8	8	in
"j":Depth Mult	0.900	0.900	0.900	0.900	0.900	
Pier Fixity	Pin-Fix	Pin-Fix	Pin-Fix	Pin-Fix	Pin-Fix	
f _m	1,500.0	1,500.0	1,500.0	1,500.0	1,500.0	psi
F _s	24,000.0	24,000.0	24,000.0	24,000.0	24,000.0	psi
Special Inspection	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Grouted Cell						
Spacing	24	24	8	24	24	in

Pier Height

This value of pier height will be used to calculate the rigidity and bending moment of each pier. This should be measured in a direction perpendicular to the direction of applied lateral loads.

Pier Length

This length should be measured in a direction parallel to the applied lateral loads, and will be used to determine rigidity, unit shear, and d distances for calculating required shear and bending reinforcement.

Pier Thickness

This thickness will be used to modify the pier rigidity by a factor of thickness/12, to adjust deflections by considering wall thickness. It will also be used to determine the actual shear stresses within the wall. Enter nominal thicknesses.

j

Because most masonry shear piers are not long bending members but actually deep beams, we have allowed the user to enter a particular j factor to be used in determining the distance from maximum tension steel to center of gravity of compression stress block. The pier length will be multiplied by j to determine the d (depth) distance from extreme compression fiber to centerline of tension steel.

Fixity Type Code

Enter the fixity condition of each pier to be used in determining individual pier rigidities. Only Pinned-Fixed and Fixed-Fixed restraint conditions are allowed.

f'm

Enter the allowable masonry strength to be used in the analysis. The allowable bending and axial stresses calculated from F'm are outlined in a later section. If the user has chosen not to use special inspection, both allowable axial and bending stresses will be multiplied by 1/2.

Fs

Enter the allowable tension strength of the reinforcing to be used. This value will be used as entered to determine the interaction equations for the design being performed.

Special Inspection

In this location, enter a 1" to specify if special inspection will be used, therefore allowing full F'm based masonry stresses to be used. Entering a 0" specifies that special Inspection will not be performed, and a multiplier of 1/2 will be applied to F'm based allowable stresses.

Grouted Cell Spacing

This entry specifies the spacing at which the vertical cells are grouted, and controls the determination of equivalent solid thickness (recalled from an internal table).

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results / Summary Tab

Results Sketch Printing					
Summary Analysis Data					
Shear Reinforcement...					
	<u>Pier #1</u>	<u>Pier #2</u>	<u>Pier #3</u>	<u>Pier #4</u>	<u>Pier #5</u>
$f_v = V / (12 * est * j * d)$	2.86	6.75	23.00	35.19	4.97 psi
Fv: w/o Reinf.	46.55	46.55	46.55	46.55	46.55 psi
Fv: w/ Reinf.	77.27	77.27	77.27	77.27	77.27 psi
Horiz. Av Req'd	Not Req'd	Not Req'd	Not Req'd	Not Req'd	Not Req'd
Bending Reinforcement...					
	<u>Pier #1</u>	<u>Pier #2</u>	<u>Pier #3</u>	<u>Pier #4</u>	<u>Pier #5</u>
Moment @ End	9.64	36.38	181.24	197.64	17.39 k-ft
"d" to tension As	4.50	7.20	10.80	11.25	5.17 ft
Bending As Req'	0.07	0.16	0.53	0.55	0.07 in ²

$f_v = V / (12 * EST * j * d)$

This is the actual shear stress within each pier, considering the tributary applied force, length, j, and equivalent solid thickness.

Fv w/o Reinforcing

This is the code allowable shear stress for piers without reinforcing.

Fv with Reinforcing

This is the code allowable shear stress for piers with reinforcing.

Horiz. As Required

Reinforcing area required to take shear if the shear stress exceeds the Fv w/o Reinforcing value.

Moment

Calculated moment in the pier using the tributary pier force and pier height.

d to Tension As

This is equal to j times the pier length.

Bending As Required

Using the bending moment calculated above, an iteration process using actual j values is executed to determine the required bending reinforcement to be located at a distance of Pier Length - 8 inches.

Results / Analysis Data Tab

	Pier #1	Pier #2	Pier #3	Pier #4	Pier #5
Height/Length	3.6000	2.2500	1.0000	0.9600	2.8261
(H/L) ³	46.6560	11.3906	1.0000	0.8847	22.5713
Rel. Defl	21.9360	5.8125	0.7778	0.7132	10.9737
Sum Rigidity	2,996.57				
Rigidity = .001/Defl	45.587	172.043	1,285.714	1,402.100	91.127
% Force to Pier	0.02	0.06	0.43	0.47	0.03
Shear to Pier k	0.54	2.02	15.10	16.47	1.07
Relative Pier Deflection * 10 ⁵ in	0.000	0.000	0.000	0.000	0.000
M / (V*Depth)	4.000	2.500	1.111	1.067	3.140
Em psi	,125,000.0	,125,000.0	,125,000.0	,125,000.0	,125,000.0
Ev = 0.4 * Em psi	450,000.0	450,000.0	450,000.0	450,000.0	450,000.0

Height / Length

As an intermediate step in calculating the rigidity values, the two applicable height / length ratios are calculated.

Relative Deflection

This relative deflection will be used to determine the relative rigidities using standard equations.

Rigidity

The rigidity value of each individual pier is equal to the inverse of the stiffness.
The formulas are:

$$\text{DEFL (FIXED)} = P H^3 / (12 * E_m) + 1.2 P H / (E_v * \text{Area})$$
$$\text{DEFL (PINNED)} = P H^3 / (3 * E_m) + 1.2 P H / (E_v * \text{Area}) \text{ Rigidity} = 1 / \text{Deflection}$$

Sum Rigidities

This equals the summation of the individual rigidities of all of the piers, and is used as the denominator in calculating the distribution coefficients to each individual pier.

% of Force per Pier

Represents the percent rigidity calculated for each pier, and will be multiplied by the Total Lateral Force to give the forces applied to each pier.

Shear per Pier

This value is simply the % Force Taken Per Pier * Lateral Load, and is the force taken by each pier for the analysis.

Relative Pier Deflection

Using the calculated pier stiffness, this is the deflection that the pier will experience due to the percentage load applied to that pier.

M/(V * Depth)

This intermediate calculation is used to determine the correct formulas used to obtain the allowable masonry shear stresses.

Em

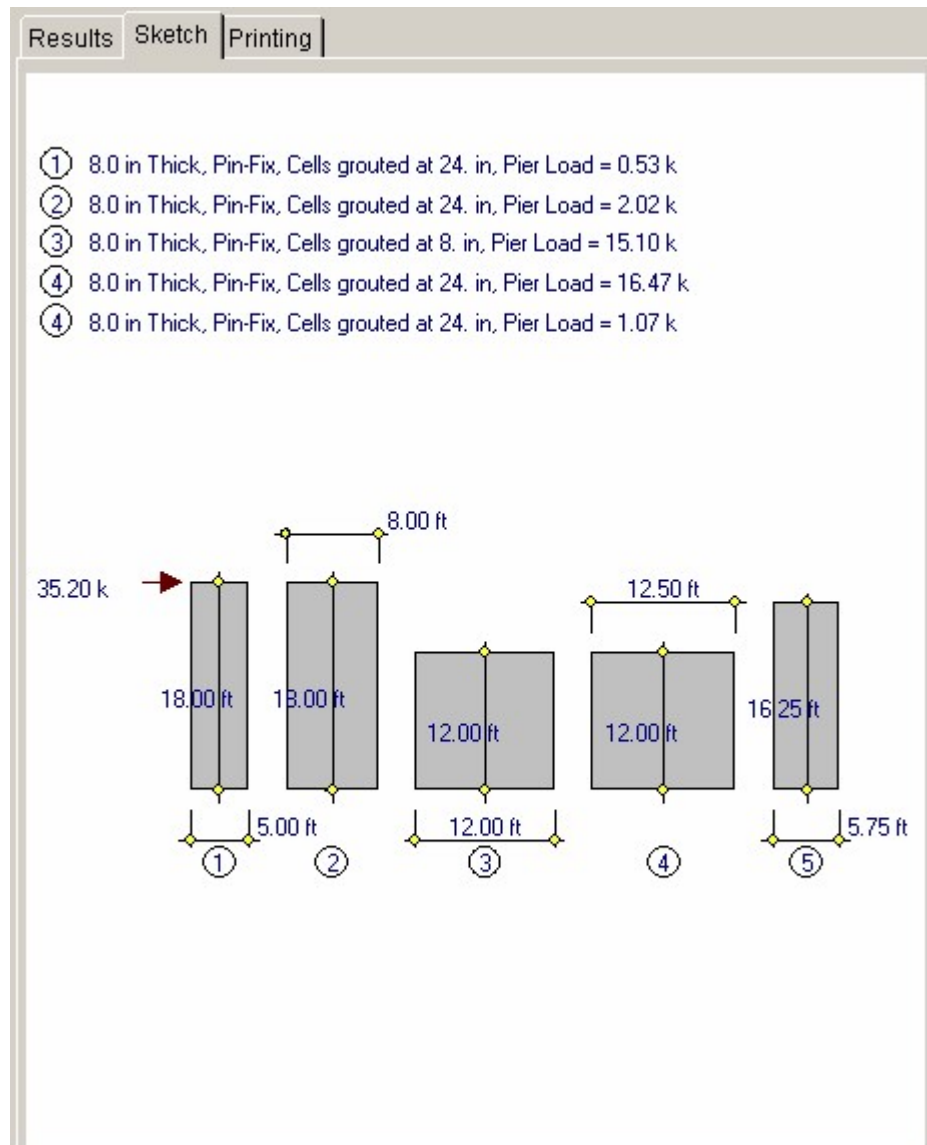
Shear modulus; used as a component in the rigidity calculation

Ev

Shear modulus; used as a component in the rigidity calculation

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Shear Pier Data	<input checked="" type="checkbox"/>
Analysis Data	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 7:12PM, 28 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 990000
 User: KW-000001, Ver 6.8.0, 10-Sep-2003
 ©1983-2003 ENERCALC Engineering Software

Masonry Pier Analysis & Design

Page 1
 c:\e03\examples\exam\Masonry Calc

Description Four pier assembly, varying lengths

General Information

Code Ref: ACI 530-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Total Lateral Force	57.10 k	Moduli: Em = fm*	750.00
Seismic Zone	4	Moduli: Ev = Em*	0.40
Load Duration Factor	1.33		

Shear Pier Data

	Pier #1	Pier #2	Pier #3	Pier #4
Pier Height	3.00 ft	3.00 ft	6.00 ft	6.00 ft
Pier Length	4.00 ft	6.67 ft	4.00 ft	8.00 ft
Wall Thickness	8 in	8 in	8 in	8 in
"j": Depth Mult.	0.90	0.90	0.90	0.90
Pier Fkty	Fix-Fix	Fix-Fix	Pin-Fix	Pin-Fix
fm	1,500 psi	1,500 psi	1,500 psi	1,500 psi
Fs	24,000 psi	24,000 psi	24,000 psi	24,000 psi
Sp Insp	No	No	No	No
Grout Spacing	32 in	32 in	32 in	32 in

Analysis Data

	Pier #1	Pier #2	Pier #3	Pier #4
Height/Length	0.7500	0.4498	1.5000	0.7500
(H/L) ³	0.4219	0.0910	3.3750	0.4219
Rel. Defl	0.2969	0.1600	2.0000	0.4375
Sum Rigidity	12,402.77			
Rigidity = .001/Defl	3,368.421	6,248.638	500.000	2,285.714
% Force to Pier	0.27	0.50	0.04	0.18
Shear to Pier	15.508 k	28.768 k	2.302 k	10.523 k
Relative Defl * 10 ⁴	0.00 in	0.00 in	0.00 in	0.00 in
M / (V*Depth)	0.417	0.250	1.667	0.833
Em	1125,000.0	1125,000.0	1125,000.0	1125,000.0
Ev	450,000.0	450,000.0	450,000.0	450,000.0

Summary

	Pier #1	Pier #2	Pier #3	Pier #4
Shear Reinforcing...				
fv=V/(12*est*d)	109.89 psi	122.25 psi	16.31 psi	37.28 psi
Fv: w/o Reinf.	30.76 psi	32.20 psi	23.28 psi	27.19 psi
Fv: w/ Reinf.	46.14 psi	48.29 psi	38.63 psi	40.78 psi
Horiz. Shear Av Req'd	fv>Fv: max	fv>Fv: max	Not Req'd in ² /ft	0.062 in ² /ft
Bending Reinforcing...				
Moment @ End	23.26 k-ft	43.15 k-ft	13.81 k-ft	63.14 k-ft
"d" to tension As	3.60 ft	6.00 ft	3.60 ft	7.20 ft
Bending As Req'd	0.20 in ²	0.23 in ²	0.12 in ²	0.27 in ²

3.6 Masonry Lintel

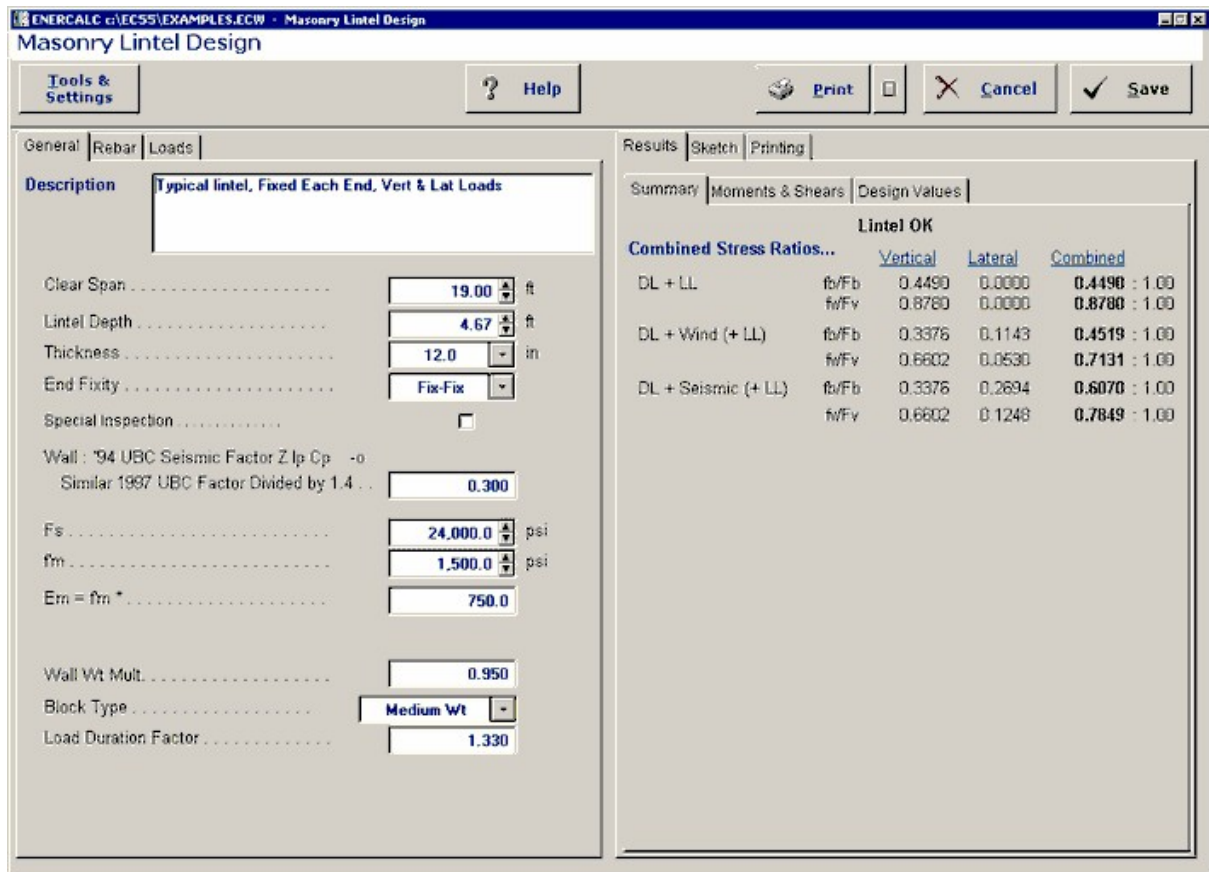
This program provides design analysis for concrete masonry lintels subject to vertical and lateral loads. Lintels can have fixed or pinned ends for most typical conditions, and the user can specify rebar sets within the depth of the lintel.

Vertical loads can be dead and live uniform and concentrated loads. You can have up to four loads of each type, and the uniform loads can be full or partial length.

The program provides analysis for both seismic and wind loads for each recalculation. You can specify seismic factors that apply to the lintel's weight and a wind load.

To allow the program to model different concrete block types, you can specify either lightweight or medium weight block, and additionally enter a lintel weight multiplication factor.

For both the vertical and lateral bending and shear directions, the program calculates allowable bending moments and shear stresses. Also, for both directions, actual moments and shears due to all entered loads are calculated. Final results consist of combined stress ratio calculations for all combinations or dead, live, seismic, and wind vertical and lateral moments and shears.



Basic Usage

- Enter Allowable Stresses And Stress Increase Factors. This program allows you to enter the f_m multiplier used to calculate E_m , as well as whether special inspection is used or if live loads should be included with seismic or wind loads (we call them Short Term (ST) loads). The seismic factor multiplies the lintel weight and uses the

result as the lateral load acting on the lintel (in the same direction as wind load).

- Enter Lintel Data. Clear span is the net opening width the lintel. Depth is the lintel's height, used for vertical bending resistance and weight calculations. Thickness should be entered as NOMINAL thickness. The program extracts wall weight and equivalent solid thickness from internal tables. Using the Fixity entry you can specify whether the lintel has fully fixed end or pinned ends (in both vertical and lateral directions).
- Enter Reinforcing Data. The program works on the concept that you will have pairs of rebars spaced vertically up and down the depth of the lintel. Only the top and bottom sets will be used for vertical bending capacity. Only the bars on one face from each bar set, placed at each face of the lintel, will be used to calculate lateral bending capacity. Please see the example of how the six entries are used correctly.
- Applied Loads allow you to place up to eight dead and live loads on the lintel. When entering Distributed Loads, you can specify a full length load by either leaving both X Left and X Right blank, or setting X-Right equal to the lintel span.
- Review the SUMMARY tab for overstress cases (which will be flagged as No Good). The most important values in this section are the six values listed in the upper right corner under the word combined.
- NOTE! Please be aware that the Load Duration Factor is applied to allowable values, so all stress ratios must be less than 1.0 for a satisfactory design.
- When satisfied, you can Print or Save the data for the current calculation, Reset the calcsheet, or use the Access Menu to choose another program.

Unique Features

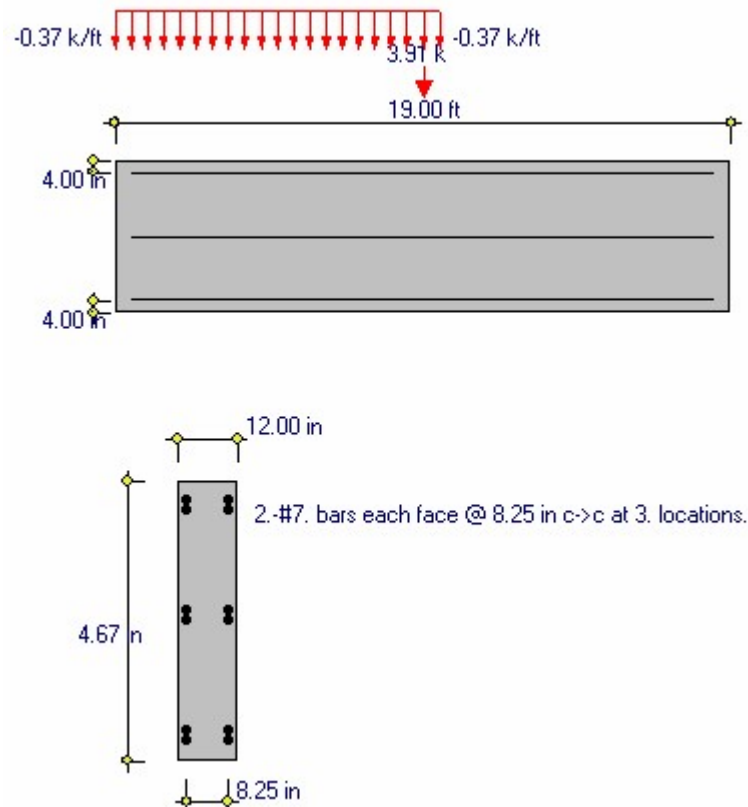
- This program calculates all vertical and lateral moments and shears and combines them for all possible stress ratios. This is a very thorough evaluation of combined stresses for seismic and wind design.
- Allowance is made for you to modify the material weight, selectively omit live load from seismic or wind loadings, and models both fix-fix and pin-pin end fixity conditions.

Assumptions & Limitations

When the lintel's fixity is set to Fixed both vertical and lateral bending are considered fixed.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Tab

General		Rebar	Loads
Description Typical lintel, Fixed Each End, Vert & Lat Loads			
Clear Span	19.00	▲▼	ft
Lintel Depth	4.67	▲▼	ft
Thickness	12.0	▼	in
End Fixity	Fix-Fix	▼	
Special Inspection	<input type="checkbox"/>		
Wall : '94 UBC Seismic Factor Z Ip Cp -o Similar 1997 UBC Factor Divided by 1.4 ..	0.300		
Fs	24,000.0	▲▼	psi
f _m	1,500.0	▲▼	psi
E _m = f _m *	750.0		
Wall Wt Mult.	0.950		
Block Type	Medium Wt	▼	
Load Duration Factor	1.330		

Clear Span

Span length of the lintel used for all bending and shear stress calculations.

Lintel Depth

Total depth (or height) of the lintel.

Thickness

NOMINAL thickness of the lintel.

Fixity

This controls how moments and shears are calculated, by specifying whether the beam is fixed at each end or pinned at each end.

Special Inspection

Enter Y if special inspection will be used during the lintel's construction. A No entry here will reduce all allowable stresses by 1/2.

Seismic Factor

This value will be applied directly to the lintel weight to generate the lateral seismic load acting on the

lintel.

F_s

Allowable steel yield strength. Typically, enter 24,000 for Grade 60 rebar, 20,000 for Grade 40.

f'_m

Basic masonry strength, psi.

Em = f' * (entry)

This value will be multiplied by f'_m to calculate Em. This value varies between code, and is typically 75 or 1,000.

Weight Multiplier

This multiplier can be used to further factor up or down the unit weight of the lintel. The lintel weight is retrieved from internal tables using your specification of nominal wall thickness and block type. THE LINTEL IS CONSIDERED FULLY GROUTED.

Block Type

This entry controls what block type is being used for determining the wall weight to be recalled from the internal tables. Select Lightweight, Medium Weight, or Normal Weight.

Duration Factor

This factor will be applied to all allowable stress values when short term seismic or wind loads are included in that combination.

Rebar Tab

General Rebar Loads

Rebar Size

Bars E/F

One Bar Each Face Shown

Rebar Distance from Top and Bottom of Lintel to Centerline of rebar group

At Top in

At Bottom in

Bar Sets

3 bar sets shown

Bar Spacing in

Rebar Size

Enter the rebar size used for all longitudinal bar sets to be used in the lintel.

Bars E/F@ Location

Enter the number of rebars at each face of the wall for each bar set. In the example problem, only one #6 was used on each face for all three bar sets.

Clearance @ Top & Bottom

Distance from the top and bottom of the lintel respectively to the center of area of the bar set. These distances will be used as d for vertical bending strength calculations.

Bar Sets Vertically

Enter the number of bar sets in the lintel.

Spacing Between Bars

This is the clear distance between the bars on each face in a bar set. IT IS ASSUMED THAT THE BARS ARE CENTERED ALONG THE LINTEL VERTICAL CENTERLINE. d used for lateral bending strength calculations is calculated as: $\text{Spacing Btwn Bars} + (\text{Actual Thickness} - \text{Spacing Btwn Bars}) / 2$

Loads Tab

General		Rebar		Loads	
Include Live Loads with Wind & Seismic Loads ? <input type="checkbox"/>					
Wind Load				15.000 psf	
Point Loads...					
	<u>Dead Load</u>	<u>Live Load</u>		<u>Distance</u>	
#1	1.540 k	2.370 k		9.50 ft	
#2				0.00 ft	
#3				0.00 ft	
#4				0.00 ft	
Distributed Loads...					
	<u>Dead Load</u>	<u>Live Load</u>	<u>Start X</u>	<u>End X</u>	
#1	0.250 k/ft	0.125 k/ft	0.00 ft	10.00 ft	>>
#2			0.00 ft	0.00 ft	>>
#3			0.00 ft	0.00 ft	>>
#4			0.00 ft	0.00 ft	>>

Wind Load

Wind load applied to the projected surface of the lintel (Span * Depth).

Point Loads & Distance

You may use this entry to apply up to four concentrated dead and live loads to the lintel. Distance refers to the distance from the left end of the lintel to the location of the load.

Distributed Loads

You may use this entry to apply up to four full or partial length uniform dead and live loads to the lintel.

X Left

Distance from the left end of the lintel to the start of the load. Use 0" for full length loads, or partial length loads that begin at the left support.

X Right

Distance from the left end of the lintel to the end of the load. For full length loads, you can enter 0" or the span length here.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results / Summary Tab

This area summarizes all the combined stresses, actual moments and shears, and allowable moments and shears. The Combined values for Moment and shear are the ratio of actual/allowable value. The Combined values in the upper right corner combine both lateral and vertical load stress ratios for shear and bending components, and these values should all be less than 1.0" for a satisfactory design. (The Load Duration Factor" was already applied to the allowable stresses).

Results Sketch Printing				
Summary Moments & Shears Design Values				
Lintel OK				
Combined Stress Ratios...		<u>Vertical</u>	<u>Lateral</u>	<u>Combined</u>
DL + LL	fb/Fb	0.3297	0.0000	0.3297 : 1.00
	fw/Fv	0.9866	0.0000	0.9866 : 1.00
DL + Wind (+ LL)	fb/Fb	0.1870	0.0909	0.2779 : 1.00
	fw/Fv	0.5827	0.0512	0.6339 : 1.00
DL + Seismic (+ LL)	fb/Fb	0.1870	0.2141	0.4011 : 1.00
	fw/Fv	0.5827	0.0512	0.7022 : 1.00

Results / Moments & Shears Tab

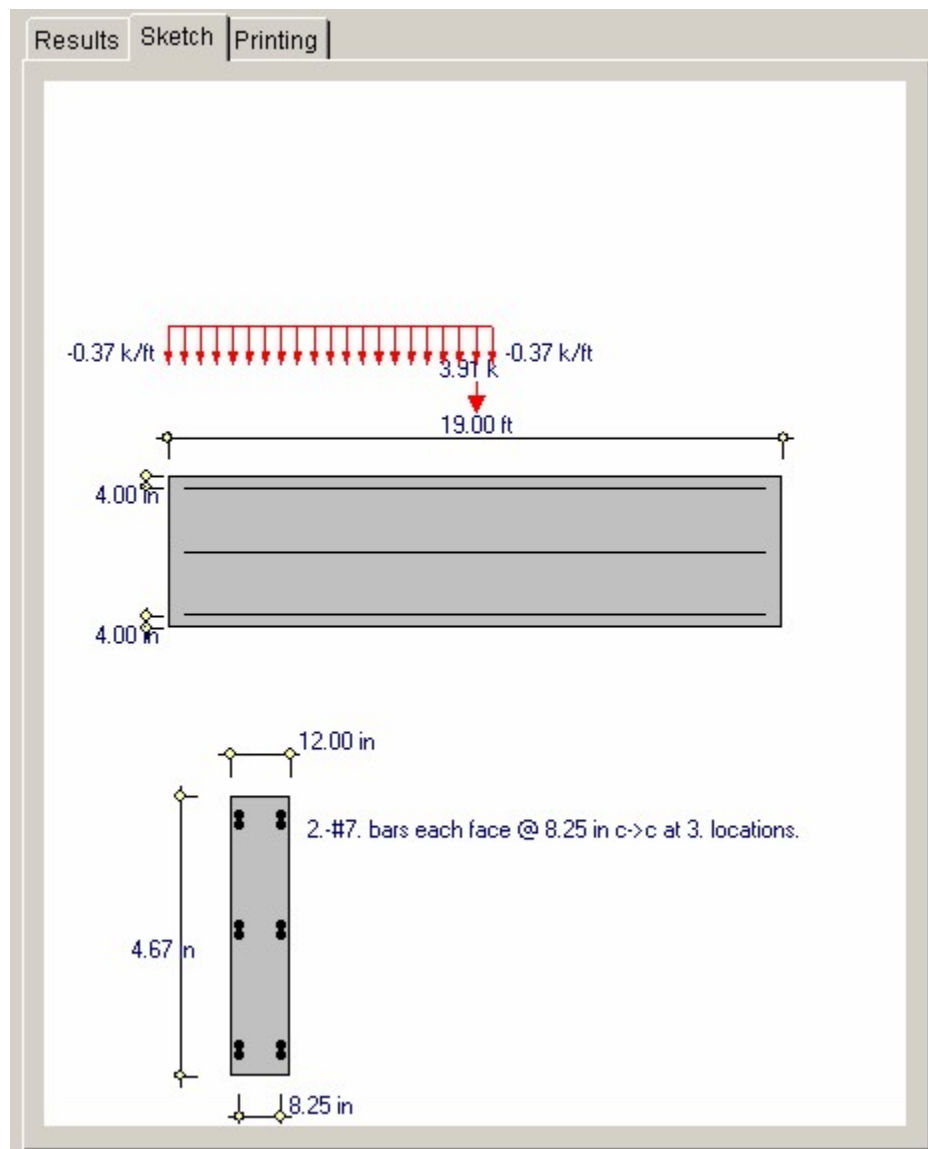
Results	Sketch	Printing
Summary	Moments & Shears	Design Values
Moments		
	<u>Moments</u>	
Vertical Loads	<u>Actual</u>	<u>Allowable</u>
DL Only	25.67 k-ft	103.20 k-ft
DL + LL	34.02 k-ft	103.20 k-ft
DL + Wind/Seismic + (LL)		137.25 k-ft
Lateral Loads		
Wind	2.11 k-ft	23.19 k-ft
Seismic	4.96 k-ft	23.19 k-ft
Shears		
	<u>Shear</u>	
Vertical Loads	<u>Actual</u>	<u>Allowable</u>
DL Only	15.01 psi	19.36 psi
DL + LL	19.11 psi	19.36 psi
DL + Wind/Seismic + (LL)		25.76 psi
Lateral Loads		
Wind	1.32 psi	25.76 psi
Seismic	3.11 psi	25.76 psi

Results / Design Values Tab

Results		Sketch	Printing
Summary		Moments & Shears	Design Values
Vertical Strength			
As			2.4000 in ²
$k:((np)^2+2np)^{.5-n}$			0.36
np			0.1023
$j = 1 - k/3$			0.880
M:mas=Fb k j b d ² /2			103.20 k-ft
M:Stl = Fs As j d			219.70 k-ft
Lateral Strength (Checking lateral bending for span)			
As			1.80 in ²
$k:(np^2+2np)^{.5-np}$			0.33
np			0.08
$j = 1 - k/3$			0.89
M:mas=Fb k j b d ² /2			23.19 k-ft
M:Stl = Fs As j d			43.13 k-ft
Allowable Stresses			
Masonry Fb...			
0.33 fm (.5 if w/o sp insp)			247.50 psi
Steel			24,000.00 psi
Masonry Fv			
$fm^{.5} * (.5 \text{ if w/o sp insp})$			19.36 psi
Equiv. Solid Thickness		11.600 in	
Wall Weight		117.80 psf	
E		1,125,000 psi	
n		25.78	

Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Printing Tab

This tab allows you to control which areas of the calculation to print. Checking a box will signal that the information described by the item will be printed. However, if there is no information in for a particular selection it will not be printed. So these checkboxes are best described as "If this particular area of the calculations contains data then print it".

Results | Sketch | Printing |

Please select printout sections to be printed...

General Information	<input checked="" type="checkbox"/>
Applied Loads	<input checked="" type="checkbox"/>
Moments & Shears	<input checked="" type="checkbox"/>
Summary	<input checked="" type="checkbox"/>
Design Values	<input checked="" type="checkbox"/>

Note: When all are selected, the software will still omit unused sections

Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 7:10PM, 28 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library

Rev: 590000 User: 10/23/2003 10:58:03, 10-Sep-2003 (c)1983-2003 ENERCALC Engineering Software Page 1
 c:\e2\examples.exe\masonry Calc

Description Typical lintel, Fixed Each End, Vert & Lat Loads

General Information Code Ref: ACI 530-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

f'm	1,500.0 psi	Clear Span	19.00 ft	Rebar Size	7
Fs	24,000.0 psi	Lintel Depth	4.67 ft	# Bars E/F	1
Em = f'm *	750.00	Thickness	12.00 in	Top Clear	4.000 in
No Special Inspection		End Fixity	Fix-Fix	Botm Clear	4.000 in
Seismic Factor	0.300	Bar Spacing	7.250 in	# Bar Sets	2
Wall Wt Mult.	0.950			Load Duration Factor	1.330
Block Type	Medium Vlt	Live Loads Not Included with Wind/Seismic			

Applied Loads

Point Loads..	DL	LL	Distance
#1	14.00 k	0.00 k	9.500 ft
Wind Load	15.00 psf		

Moments & Shears

Vertical Loads	Moment		Shear	
	Actual	Allowable	Actual	Allowable
DL Only	49.80	80.49 k-ft	22.23	19.36 psi
DL + LL	49.80	80.49 k-ft	22.23	19.36 psi
DL + Wind/Seismic + (LL)		107.05 k-ft		25.76 psi
Lateral Loads				
Wind	2.11	18.43 k-ft	1.36	25.76 psi
Seismic	4.96	18.43 k-ft	3.21	25.76 psi
Equv. Solid Thick	11.600 in	Wall Wt	117.80 psf	E 1125,000.0 psi
				n 25.7778

Summary **Lintel Overstressed !**

Span= 19.00ft, Depth= 4.67ft, Thick= 12.00inMedium Weight Block, No Special Inspection
 Using 2 bar sets of 1- #7 bars spaced 7.250in apart, Ends are Fix-Fix

Combined Stress Ratios

DL + LL	(shear governs)	1.1480	: 1.00
DL + Wind (+ LL)	(shear governs)	0.9161	: 1.00
DL + Seismic (+ LL)	(shear governs)	0.9879	: 1.00

Combined Stress Results..

	fb/Fb	fv/Fv	Vertical	Lateral	Combined
DL + LL	0.6187	1.1480	0.6187	1.1480	: 1.00
DL + Wind (+ LL)	0.4652	0.8631	0.4652	0.8631	: 1.00
DL + Seismic (+ LL)	0.4652	0.8631	0.4652	0.8631	: 1.00

Design Values

Vertical Strength	Allowable Stresses
As	Masonry Fb..
k:(np ² +2np) ^{0.5} -np	0.33 fm (.5 f w/o sp insp)
np	247.50 psi
j = 1 - 1/3	Steel
M:mas=Fb k j b d ² /2 *LDF	24,000.00 psi
M:Stl = FsAs j d	Masonry Fv
	fm*.5 *(.5 if w/o sp insp)
	19.36 psi
Lateral Strength	
As	
k:(np ² +2np) ^{0.5} -np	
np	
j = 1 - 1/3	
M:mas=Fb k j b d ² /2 *LDF	
M:Stl = FsAs j d	

Part



4 Retaining Wall Design Modules

All three retaining wall design programs provide a thorough and complete solution for virtually any common retaining wall. The three modules are called :

- **Cantilevered Retaining Wall**
- **Restrained Retaining Wall**
- **Tapered Stem Retaining Wall**

All programs have these characteristics:

- Variable Toe & Heel dimension, footing keys
- Variable soil height over to and heel with backfill angle behind heel.
- Loading for soil, surcharge, adjacent footing, vertical on stem, and general lateral loads.
- Cantilevered wall allows you to design up to 5 stem sections of different material and design specifications.
- Tapered stem wall is concrete only and you can specify front and rear stem angles.
- Restrained wall program allows you a constant thickness stem in concrete or masonry.
- All programs do a thorough analysis of overall sliding and overturning stability, soil pressure, footing design, and stem design.

4.1 Cantilevered Wall

This program provides calculation procedures necessary to perform complete design and analysis of a conventional cantilevered retaining wall.

The retaining wall may be loaded with any of the following load combinations :

- Any angle of sloped backfill.
- Surcharge loading above heel or toe.
- Eccentric axial dead and live load on stem.
- Lateral and vertical load from an adjacent footing.
- Wind or seismic force on projecting portion of stem.
- An additional uniform lateral load may be applied to the wall.

The following overall dimensions can be specified:

- Retained height.
- Toe and heel dimension.
- Wall extension above retained height.
- Footing key depth, width, and location.

- Soil height over the toe.

The following stability checks are performed:

- Total overturning and resisting moment.
- Optional Inclusion of vertical active pressure on the rear face of the wall to resist overturning.
- Sliding resistance using both passive and active pressure.
- Both heel and toe of the footing are designed as follows:
 - Toe Design - Find actual moment at stem face, check required minimum reinforcing, list rebar choices, and check one-way shear.
 - Heel Design - Find moment at stem face, check required minimum reinforcing, list rebar choices and check one-way shear. User may neglect upward soil pressure for conservative design.

Stem Design: Up to five ascending stem sections, either masonry or concrete, may be selected. User enters whether masonry or concrete, thickness, rebar size and location, and special inspection status. Program determines maximum rebar spacing (at 8" modules for masonry), and checks shear at bottom of section

Also, the program has the unique ability to design screen walls (freestanding walls where the retained height is low and the projection above the soil is higher). Wind and seismic loads may be applied to the projecting portion, and an increased allowable stress may be used as allowed for short term loadings.

ENERCALC c:\ECSS\EXAMPLES.ECWX - Cantilevered Retaining Wall

Cantilevered Retaining Wall

Tools & Settings ? Help Print Cancel Save

Key Reinf. Req'd Overturning ≥ 1.5 O 3rd Stem Bending Overstress
 Sliding ≥ 1.5 OK Ftg Shear OK Soil Press NG!

Criteria | Loads | Stem | Footing | Stability | Description | Results | Construction | Wall Loading |

General Data | Material Data | Options |

General

Retained Height 8.000 ft

Wall height above retained soil 3.000 ft

Height of Soil over Toe 12.000 in

Water table height over heel 0.000 ft

Soil Values

Soil Slope 2.0 : 1

Allow Soil Bearing 2,000.0 psf

Lateral Pressure Method E.F.P.

Active Soil Pressure - Heel Side 45.00 psft

..... 35.00 psft

..... 250.00

Soil Weight 110.00 pcf

Basic Usage

- Entering Soil Data specifies the lateral earth pressures applied to the wall. Active Pressure will be used on over toe and/or heel unless Slope is non-zero. If this is the case, then the soil is sloped and Slope Pressure will be used behind the wall to generate lateral loads. Maximum Pressure can be entered to instruct the program to limit the lateral pressure intensity. (The pressure diagram then becomes uniform). Passive Pressure will be used for the full depth of soil in front of the wall to resist sliding. Soil Density will be used for soil weight, and Soil Height Over Toe will be used to define passive pressure height, vertical load, and will create an active pressure resisting overturning.
- You can apply two additional vertical Loads: an Axial Load to the top of the stem (with optional eccentricity), and Toe and Heel Surcharges. If the heel surcharge is permanent, you can specify that it Should Be Used To Resist Overturning.
- In addition to the lateral loads created by the soil above the footing, you can apply additional Lateral Loads to the wall. Enter a Lateral Loads Acting on the Stem Above Soil when your wall will extend above the soil, such as a screen or guard wall. Impact and bracing loads can be applied to the wall using the Additional Lateral Load item, letting you specify a load intensity and length. You can also enter an Adjacent Footing Load, by specifying the magnitude of load and position relative to the rear of the topmost stem section.

- The Wall and Footing Data section is used to specify the retained height, stem height above soil, and footing dimensions. Zero entries are permitted for the key and either toe or heel width. While using the program, you can easily change these values often and recalculate [F9] to determine soil pressures, overturning stability, and sliding stability.
- The critical footing wall design values are given in the Summary area, where you can review calculated results and then modify the wall and footing data as required.
- The program will perform a Sliding Check when you enter Footing/Soil Friction coefficients, and can Neglect a certain height of soil, if the soil in front of the wall is non-compacted.
- By simply entering the concrete strength, steel strength, and minimum steel percentage the program will provide a full Footing Analysis and Rebar List.
- Stem Design can be performed for up to five independent sections of the wall. By specifying Wall Construction Type, Design Height, and Wall Thickness and Reinforcing, each stem section can be easily refined for an optimum design.
- The Summary of Overturning and Resisting Moment table should be reviewed if you have any questions on how the vertical and lateral loads are being applied to the wall.
- When you are satisfied with the wall, Print or Save the current worksheet, choose Reset to start another wall design, or use the Access Menu to choose another program.

Unique Features

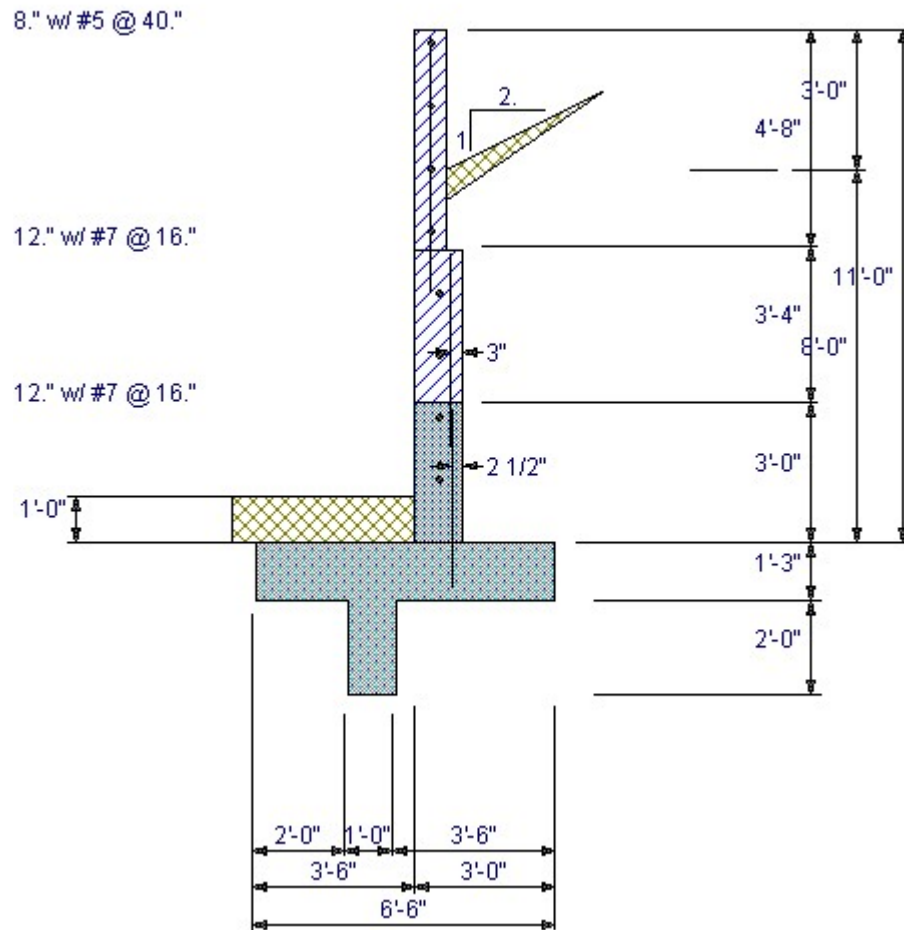
- Slope of backfill may be varied from flat to 45 degrees.
- Either a concrete or masonry stem can be specified. When concrete is chosen, the wall thickness, rebar size, and location is used to calculate the minimum spacing for the rebar. When masonry is specified, the option of special inspection is entered in addition to the above values, and the maximum rebar spacing is calculated at 8" modules.
- The program has the unique ability to design screen walls for conditions where the wall extends a distance above the soil which is much greater than the retained height.

Assumptions & Limitations

- Both active and passive pressures are applied as Equivalent Fluid Pressures.
- Friction coefficient is assumed to be applicable for both friction only and friction combined with passive pressure cases.
- Design for bending reinforcement in Toe and/or Heel of footing is calculated using $d = \text{thickness} - 3"$.
- If surcharge exists above the Toe or Heel, the soil height over those areas will be increased (internally) by the ratio of Surcharge/Soil Density.
- All concrete design is based on ACI Ultimate Strength Design.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Data Tab

Criteria	Loads	Stem	Footing	Stability	Description
General Data Material Data Options					
General					
Retained Height	8.000 ft				
Wall height above retained soil	3.000 ft				
Height of Soil over Toe	12.000 in				
Water table height over heel	0.000 ft				
Soil Values					
Soil Slope	2.0 : 1				
Allow Soil Bearing	2,000.0 psf				
Lateral Pressure Method	E.F.P.				
Active Soil Pressure - Heel Side	45.00 psf/ft				
Active Soil Pressure - Toe Side	35.00 psf/ft				
Passive Pressure	250.00				
Soil Weight	110.00 pcf				

Retained Height

This is the height of retained earth measured from top of footing to the top of soil behind the stem (over the heel). When the backfill is sloped, the soil will slope away and upwards from this height. The actual retained height used for overturning and soil pressure calculations will be the retained height projected at the vertical plane of the back of the heel, but for stem moments, no such increase will be made. Using the spin-buttons you can vary this in 3-inch increments (you can type in any number). After each entry you can press the tab key to advance to the next entry, or use your mouse to position the cursor.

Wall Height Above Retained Soil

Use this entry to specify if the wall extends above the retained height. This entry is typically used to define a "screen wall" projection above the soil retained. This extension can be used as a weightless "Fence" or a concrete or masonry stem section without any soil retained behind it. You can enter wind load on this projection using the entry "Load @ stem above soil" on the "Loads" tab. We'll handle the fence when we get to the STEM design screen.

Height of Soil Over Toe

Measured from the top of footing to top of soil, this may vary from a few inches to a few feet (it is measured in inches) depending upon site conditions. It is used to calculate passive soil pressure depth (considering "Ht. to Neglect" on "Sliding" tab). This soil can also be used to calculate an active pressure to reduce overturning; this is a choice on the Options Screen, and can have significant effect if the footing is well below grade.

Water Table Height Over Footing

If you want to design for a water table condition, enter the maximum height from top of footing to water table level. The program will then compute the added pressures for saturated soil on the heel side of the footing, including buoyancy effect, to calculate increased moments and shears on the stem, and overturning. Do not enter a height greater than the retained height, nor a liquid other than water.

Soil Slope

You may enter any backfill slope behind the wall. Use the drop-down menu or type the slope ratio as Horiz/Vert. The soil must be level or slope upward. Negative backfill slopes (grade sloping downward, away from the wall) are not allowed.

The program will use this slope to 1) include the weight of a triangular wedge of soil over the heel as vertical load, and 2) compute overturning based upon an assumed vertical plane at the back face of the footing extending from the bottom of the footing to ground surface - a steeper slope will result in a higher overturning moment. We suggest not using a slope steeper than 1.5 to 1.0 unless approved by the geotechnical engineer. The program will not accept a backfill slope steeper than the angle of internal friction.

Allowable Soil Bearing

The maximum allowable soil bearing pressure for static conditions. Using the spin buttons you can increment in 50 psf steps. Usual values for this vary from 1,000 psf to 4,000 psf or more.

Lateral Pressure Method

Here you can choose between E.F.P. or Rankine formula or Coulomb formula. EFP means "Equivalent Fluid Pressure," where you can enter a lateral soil pressure in psf per foot of depth. "Rankine" or "Coulomb" instructs Retain Pro to use the Rankine or Coulomb Method to calculate active and passive soil pressures using an entered angle of internal friction for the soil. When Rankine or Coulomb is chosen, the $K_a \cdot \text{Density}$ value for active pressure is computed.

Active Soil Pressure - Heel Side (EFP Method Chosen)

Active Pressure: $K_a \cdot \text{Gamma}$ (Rankine or Coulomb Method Chosen)

Enter the equivalent fluid pressure (EFP), or the angle of internal friction if Rankine or Coulomb is chosen, for the soil being retained that acts to overturn and slide the wall toward the toe side. This pressure acts on the stem for stem section calculations, and on the total footing+wall+slope height for overall stability and soil pressure calculations.

Commonly used values, assuming an angle of internal friction of 34, are 30 pcf for a level backfill; 35 pcf for a 4:1 slope; 38 pcf for a 3:1 slope; 43 pcf for a 2:1 slope; and 55 pcf for a 1.5:1 slope. These values are usually provided by the geotechnical engineer. If the Rankine or Coulomb method had been chosen, these values will be computed using those formulas.

When the retained soil is sloped, a vertical component of the lateral earth pressure over the heel can be applied vertically downward in the plane of the back of the footing. You can choose to apply this force for overturning resistance, sliding resistance, and/or for soil pressure calculations, by checking the boxes on the CRITERIA > Option screen.

Angle of Internal Friction (Rankine or Coulomb Method Chosen)

This value is entered in degrees and is the angle of internal friction of the soil. This value is usually provided by a geotechnical engineer from soils tests, but can also be found in reference books or building codes for various typical soil classifications. This value is used along with Soil Density within the standard Rankine and Coulomb equations to determine " K_a " and " K_p " multipliers of density to give active and passive soil pressure values.

Active Soil Pressure - Toe Side

If the EFP method is chosen, enter the active pressure to be used on the toe side of the wall. This active pressure is used along with the "Soil Height over Toe" value (entered on the Sliding tab) to calculate a stabilizing soil force on the wall. This front side of the wall is assumed to be level.

When either the Rankine or Coulomb method is chosen, the angle of internal friction is used in the

Rankine formula with an assumed level toe-side slope.

The active pressure from soil over the toe partially counteracts the heel-side active pressure for overturning calculations.

Passive Pressure (EFP Method Chosen)

Passive Pressure: $K_p * \text{Gamma}$ (Rankine or Coulomb Method Chosen)

This is the resistance of the soil in front of the wall to being pushed against to resist sliding. Its value is in psf per foot of depth (pcf). For the E.F.P. method, you input this value, which is usually obtained from the geotechnical engineer. If the Rankine or Coulomb method is chosen, it will be computed and entered for you. Its value usually varies from 100 pcf to about 350 pcf.

Soil Density

Enter the soil density for all earth above the toe and heel of the footing. This weight is used to calculate overturning resistance forces and soil pressures using the weight of the soil block over the projecting toe and heel of the footing. When surcharges are applied over the soil, the surcharges are transformed to equivalent uniform lateral loads acting on the wall by the ratio force = (Surcharge/Density)*Lateral Load. Input this value in lbs. per cubic foot. Usual values are 110 pcf to 120 pcf.

Material Data Tab

This screen allows you to change properties of masonry and concrete. It also allows you to decide what load factor (1.4 or 1.7) to use for factored soil pressure attributable to dead loads.

Criteria | Loads | Stem | Footing | Stability | Description

General Data | Material Data | Options

Masonry

Concrete block type **Lightweight** ▾

Factor applied to f_m
for calculation of E_m **750.0**

Multiplier applied to
wall weight from tables **1.000**

Concrete

Concrete Weight **145.00** ▲ pcf ▾

ACI Factored Soil Pressure

Load Factor Used For Upward Factored Soil Pressure...

Calculate using 1.4*DL + 1.7*LL ▾

For Masonry

Concrete Block Type

This allows you to select Lightweight, Medium weight, or Normal weight concrete masonry units.

Factor Applied to f'_m for Calculation of Em

The modulus of elasticity for masonry is $750 f'_m$ (UBC '97 2106.12.1). This entry allows you to select a multiplier other than 750.

Multiplier Applied to Wall Weight from Tables

This entry allows you to increase or decrease the internal default values of stem weights, as displayed on the STEM screen.

For Concrete**Stem concrete weight**

This is usually 145-150 pcf, but may be changed with this entry.

Footing concrete weight

This option is necessary since if there is any buoyancy effect, this will reduce the effective weight of the footing concrete.

ACI Factored Soil Pressure

This gives you two choices for computing the factored moment in the toe. Select either a 1.7 load factor for both dead load and pressure attributable to live load and lateral soil pressure on the wall. Alternatively, and less conservative, use a load factor of 1.4 for dead load (footing and superimposed earth) and 1.7 for live load and upward soil pressure attributable to lateral soil pressure.

Options Tab

This screen is critical to your design, since many subsequent calculation results will be affected. Review and check these boxes carefully.

Criteria	Loads	Stem	Footing	Stability	Description
General Data Material Data Options					
Use AASHTO Load Factors ? <input type="checkbox"/>					
Slab is present to resist all sliding forces <input type="checkbox"/>					
Use these items when your surcharge may not be applied 100% of the time to resist the force					
Use TOE Surcharge To Resist Sliding & Overturning ? <input checked="" type="checkbox"/>					
Use HEEL Surcharge To Resist Sliding & Overturning ? <input checked="" type="checkbox"/>					
Use this item to ignore the upward soil pressure under the heel when calculating heel moments & shears.					
Neglect Upward Pressure at Heel ? <input checked="" type="checkbox"/>					
Toe Active Pressure Used.. To Resist Overturning <input type="button" value="v"/>					
Use these choices to select when to use the vertical compo of active lateral soil pressure.					
Use for Soil Pressure? <input type="checkbox"/>					
Use for Sliding Resistance ? <input type="checkbox"/>					
Use for Overturning Resistance ? <input type="checkbox"/>					

Slab is Present to Resist all Sliding Forces

Check this box when a slab is in front of the wall to resist lateral sliding. This negates sliding concerns (but check the slab if necessary). For restrained wall footings, it deletes the lateral force (base stem reaction) applied to the top of the footing, puts "not applicable" in the sliding ratio display, and dims the sliding entries on the FOOTING > KEY DIMENSIONS AND SLIDING sub-tab screen. The slab restraint is assumed to be at the top of the footing and the program does not allow it to be placed higher-if this condition occurs, append your printout with hand-calcs,

Use Toe Surcharge to Resist Sliding and Overturning

Checking this box will include the weight of soil overburden on the toe to resist overturning and add to its weight for frictional resistance.

Use Heel Surcharge to Resist Sliding and Overturning

Checking this box will include heel surcharge. If surcharge is live load and its use would be non-conservative, don't check this box.

Neglect Upward Pressure at Heel

For heel calculations you may choose to neglect the upward soil pressure, typically resulting in greater heel moment. If this box is checked the Mu for upward loads will be zero.

Toe Active Pressure Used

Checking this box will apply the toe side active pressure to reduce overturning moment and reduce sliding force to a net sliding force to be resisted.

Choices for Use of Vertical Component of Active Pressure

The vertical component of the lateral pressure is applied at a vertical plane at the back of the footing.

You can optionally use this to resist overturning, sliding, or for soil pressure calculations. (For the latter it can make a considerable difference). Checking these boxes applies the options. For a level backfill, this option will back-solve the EFP method to find the equivalent internal friction angle, then apply this vertical component equal to $\tan \phi/2$. If either the Rankine or Coulomb method had been chosen, this

vertical component would be tangent of $\phi/2$.

Note that most texts suggest using the vertical component only to resist overturning. For a level backfill these options are usually not used.

Loads / Vertical Loads Tab

Additional loads on the wall are entered on these sub-tabs.

Criteria	Loads	Stem	Footing	Stability	Description
Vertical Loads					
Lateral Loads					
Surcharges					
Surcharge over Toe		100.00		psf	
Surcharge Over Heel		100.00		psf	
Axial Load Applied to Top of Stem					
Axial Dead Load		1,000.0		lbs	
Axial Live Load		1,000.0		lbs	
Axial Load Ecc.		6.00		in	
Adjacent Footing Data					
Adjacent Footing Load . .		1,200.00		\$\$\$\$\$\$1	
Footing Width		2.000		\$\$\$\$\$\$1	
Eccentricity		0.00		in	
Wall to Ftg CL Dist		4.00		ft	
Footing Type		Line Load			
Base Above/Below Soil at Back of Wall		-1.50		ft	

Surcharge Over Toe

If other loads are imposed directly above the toe (such as a slab, storage, or moving load), these may be entered here (you have already entered the height of the soil over toe). This surcharge is divided by soil density and multiplied by active pressure to calculate an equivalent lateral load. This surcharge is used to calculate soil pressure. You can use this surcharge to resist sliding and overturning by clicking the box on the CRITERIA > Options sub-tab.

Surcharge Over Heel

This surcharge is considered uniformly applied to the top surface of the retained soil (over the heel). It may be entered whether or not the ground surface is sloped, but is always taken as a vertical force. This surcharge is divided by the soil density and multiplied by the Active Pressure to create a uniform

lateral load applied to the wall. You can use this surcharge to resist sliding and overturning by clicking the box on the CRITERIA > Options sub-tab.

Axial Loads Applied to Top of Stem

These loads are considered uniform load along the length of the wall. They are applied to the top of the topmost stem section and effect the design of masonry stems only. The dead and live loads are used to calculate stem design values and factored soil reaction pressures used for footing design. Only the dead load is used to resist overturning and sliding of the retaining wall.

Axial Load Eccentricity

This is the eccentricity of the axial load with respect to the centerline of the uppermost stem section. The eccentricity moves the load toward the toe, causing bending moments that are additive to those caused by the lateral soil pressure over the heel (negative eccentricities are not accepted).

Adjacent Footing Load

This entry gives you the option of placing a footing adjacent and parallel to the back face of the wall, and have its effect on the wall included in both the vertical and horizontal forces on the wall and footing. Refer to the General Reference Diagram for locations where input measurements should be taken.

For a "Line Load" the load entered is the total load per foot parallel to the wall (not lbs. per sq. ft).

If the adjacent footing is specified as "Square Footing" (not line load), the load entered should be the adjacent footing load divided by its dimension parallel to the wall, giving a pounds per lineal foot value, as for a continuous (line) footing.

A Boussinesq analysis is used to calculate the vertical and lateral pressures acting on the stem and footing. The program uses an assumed Poisson ratio of 0.3. (See Foundation Analysis and Design, 5th Edition, by J. E. Bowles, McGraw-Hill, pages 629-639)

Use of the Adjacent Footing may not be applicable if the horizontal distance from back face to stem to closest edge of adjacent footing is greater than the distance from top of wall footing to bottom of Adjacent Footing (i.e. outside an assumed line of influence).

When the Boussinesq analysis is used, the program may require additional computing time, depending upon the speed of your computer. To avoid this delay (which occurs any time any entry is changed) we suggest you use a vertical load of zero until your data entry is nearly finalized. Then enter the actual footing load and modify your final values.

Suggestion: For adjacent truck or highway loading, it may be preferable to use a heel surcharge (uniform) of 250 psf (or more) instead of treating it as an "adjacent footing."

Do not use this feature if the adjacent footing load is farther from the stem than the retained height, less the depth of the adjacent footing below the retained height, since at this distance it will not have significant effect on the wall.

Footing Width

Width of the adjacent footing measured perpendicular to the wall. This is necessary to create a one-foot long by Width wide area over which the load is applied.

Footing Eccentricity

This entry is provided in case the soil pressure under the adjacent footing is not uniform. Enter the eccentricity of the resultant force under the adjacent footing from the centerline of the footing. Positive eccentricity is toward the toe, resulting in greater pressure at the side of the adjacent footing closest to the stem. The program will use the vertical load and eccentricity and create a trapezoidal pressure distribution under the adjacent footing for use with the Boussinesq analysis of vertical and lateral pressures.

Wall to Footing Centerline Distance

Distance from the center of the adjacent footing to the back face of the stem at the retained height.

Footing Type

This drop down menu selection allows you to enter either an isolated footing using the "Square Footing" selection, or a continuous footing using the "Line Load" selection.

Base Above/Below Soil at Back of Wall

Use this entry to locate the bottom of the footing with respect to the Retained Height. Entering a negative number places the footing below the soil. A positive entry would typically only be used when the soil is sloped and the footing resides "uphill". To insert a negative number, first type the number then press the "-" (minus) sign.

Note: If the "Adjacent Footing" is another retaining wall at a higher elevation, the Boussinesq analysis may be used for the vertical load applied to the soil from the wall, however the design must also consider the lateral (sliding) loads from that adjacent wall. This load could be applied as "Added Lateral Load", however this is at the discretion of the designer and is not within the scope of the program. Caution is urged for this condition. See discussion in the companion book: Basics of Retaining Wall Design.

Loads / Lateral Loads Tab

The screenshot shows a software window with several tabs: 'Criteria', 'Loads', 'Stem', 'Footing', 'Stability', and 'Description'. The 'Loads' tab is selected, and within it, the 'Lateral Loads' sub-tab is active. The interface contains the following input fields:

- Load @ stem above soil:** A numeric input field with the value 15.00 and units 'psf'.
- Added Lateral Load on Stem:** A section containing three input fields:
 - Lateral Load:** A numeric input field with the value 25.00 and units '#/ft'.
 - ...Height to Top:** A numeric input field with the value 5.00 and units 'ft'.
 - ...Height to Bottom:** A numeric input field with the value 2.00 and units 'ft'.

Load @ Stem Above Soil

This load (typically a wind load) will be applied to that part of the stem projecting above the retained height defined by the entry "Wall height above retained soil." It is used to calculate overturning moment and shear, stem design moment and shear, and soil pressures. Customary values are 10 psf or higher. Only a positive "+" value can be entered (i.e., the force may only be applied in a direction to add overturning, in the direction of the active soil pressure).

Added Lateral Load

This input allows you to specify an additional uniformly distributed lateral load applied to the stem. You can use it to apply a seismic load to the wall, an additional uniform lateral load due to soil pressure, or apply a short but intense load due to impact of a car or similar force (this case can be modeled by separating the "Height to Bottom" and "Height to Top" by just one foot, and using an "Added Lateral Load" equal to the total added force). This load is factored by 1.7 to calculate concrete moments and shears.

Height to Top

This dimension defines the upper limit of the added lateral load measured from the top of the footing. Do not enter a dimension higher than the top of the wall ("retained height" plus "Wall height above retained soil").

Height to Bottom

This dimension defines the beginning (or bottom) of the added lateral load measured from the top of the footing.

Stem Tab

The layout of this screen will change depending upon whether you previously chose a conventional cantilevered wall, a tapered stem wall (earth side battered), or a gravity wall. This screen is for a straight stem non-battered wall.

Criteria	Loads	Stem	Footing	Stability	Description
3rd Material	Masonry				
Thickness	6 in				
Wall Weight	75.00 psf				
Rebar Size	# 5				
Rebar Spacing	16 in				
Rebar Position	Edge				
<input type="checkbox"/> Specify					
Rebar Depth 'd'	5.250 in				
fm	1,500.0 psi				
Fs	24,000.0 psi				
Short Term	1.000				
Special Inspection	<input checked="" type="checkbox"/>				
Solid Grouting	<input checked="" type="checkbox"/>				
n = Es / Em	25.778				
Equiv. Thick.	7.60 in				
Stem Design Heights.....					
3rd	6.33 ft				
2nd	3.00 ft				
Bottom	0.00 ft				
ft					
Insert Stem Delete Stem					
Summary					
Stress Ratio = 0.672					
Moment OK					
Actual	1,234.10 ft-#				
Allowable	2,115.92 ft-#				
Shear					
Total Force	175.72 lbs				
Actual	3.14 psi				
Allowable	38.73 psi				
Rebar Lap & Develop. Lengths...					
Development Above	30.00 in				
Lap Below	30.00 in				

Material

Use the drop down menu to select Masonry, Concrete, Fence, or None. Fence is only allowed on top of the wall, higher than the Retained Height, and is considered weightless. Use None to disable the stem section.

Thickness

Use the drop down menu to input the wall thickness. If masonry is chosen, you will be given standard masonry thickness (e.g. 6", 8", 12"). If concrete is chosen, you can increment in one-inch steps. If Fence had been chosen, this entry is unavailable since the fence is assumed to be weightless.

Wall Weight

This displayed value is based upon the wall data entered earlier. The industry standard values used by the program may be modified on the CRITERIA > Materials Screen. See Appendix C for masonry wall weights.

Rebar Size

Make your selection from the pull-down menu for bar sizes #3 to #10.

Rebar Position

Chose between Center and Edge. If Center is chosen, the rebar d distance will be 1/2 the actual wall thickness. If Edge is chosen it will be located at the heel side of the stem.

For masonry design, the program contains a table of the appropriate "d" values to use for various block sizes and center/edge locations

For concrete, the "edge" rebar depth is always stem thickness less 1.5" for #5 and smaller bars (or 2" for #6 or larger), less one-half the bar diameter. You can modify the rebar depths by using the CRITERIA > Material screen.

Specify Position Box

Clicking this box displays the default "d" value, which may change. If unchecked, the default "d" is displayed.

f'_m

Enter f'_m for masonry stems to be designed. This value is not visible when a concrete wall has been specified. Spin button changes this value in 250 psi increments.

Fs

Enter the allowable steel stress, based on working stress design, which should be used for design of the masonry stem section. Spin button changes this value in 1,000 psi increments. This value is not visible when a concrete wall has been specified.

Short Term

This is used for masonry design only, and indicates the allowable overstress multiplier (1.33 for wind and seismic, per ACI and UBC). We recommend using a value greater than one only if resulting stresses from wind or seismic are greater than those from static forces acting alone. You select from the pull-down menu.

Special Inspection

This is applicable to masonry stems only, and if checked, the full allowable f'_m used in flexure, shear, and axial stress will be used. If not checked, the allowable values will be reduced by one-half. The Uniform Building Code requires this reduction if Special Inspection is not provided.

Solid Grout

This applies to masonry only, and if this box is checked the weight of the wall will be based upon industry standard solid-grout weight for either lightweight, medium weight, or normal weight. If this box is not checked, the program will calculate the weight based upon grouting of only cells containing reinforcing.

This also affects equivalent solid thickness for stem shear calculations, and area for axial stress calculations (combined with moment for masonry stems).

Modular Ratio "n"

This is the multiplier used on f'_m to calculate the modulus of elasticity of masonry. The 1997 UBC specifies $E_m = 750 * f'_m$, which is the default value in the program. ACI 530-02, Table 5.5.1.3, lists higher values, which result in lower "n" values, hence the allowance for the user to modify it by using the CRITERIA > Material screen.

Equivalent Solid Thickness

If partially grouted (not solid grout) this value is generated from an internal database as shown below:

Masonry Equivalent Solid Thickness (inches)

Thickness (inches)		Grout Spacing			
		8"	16"	24"	32"
40"	48"	5.6	4.5	4.1	3.9
3.8	6	3.7	7.6	5.8	5.2
4.7	8	4.6	9.6	7.2	6.3
5.7	10	5.5	11.6	8.5	7.5
6.7	12	6.5	13.6	9.9	8.7
7.6	14	7.4	15.6	11.6	10.1
8.6	16	8.3			9.5

Stem Design Heights

IMPORTANT! The term "Design Height" used in this program is the height above the top of the footing (i.e. base of stem) where you want to check the design. It calculates moments and shears applied above that point.

You can divide the stem into up to five sections (increments of height). Each increment represents either a different material (concrete, masonry, or fence), thickness, or a change in reinforcing size or spacing.

For most walls, only two or three changes in stem sections are used, for example, at the top of the dowels projecting into the stem from the footing and perhaps further up the wall where a more economical section is desired.

Bottom

You must start your stem design here, at the base (height above footing = 0.00), where the stem moment and shear is maximum. As you manipulate the bar sizes, spacing, and position (you first, of course, will have selected a wall material and trial thickness) until the Summary box shows you an acceptable stress ratio (the higher and closer to 1.0, the more efficient).

To check the wall at a higher Design Height, such as at least the LAP REQ'D IF ABOVE distance, where reinforcing or thickness can be reduced, click the **Insert Stem** button and enter the next higher section. Advance the spin button to the desired height above the top of the footing or enter it by typing. This will move (and dim) the Bottom Section and you can now design this "2nd" section.

Continue this way, clicking Insert Stem after each stem section design is completed, up to a maximum of five heights. A new Design Height should only be entered when you want to change the material, thickness, or reinforcing, and should never be less than about two foot intervals.

Summary -- Overall Stress Ratio

For masonry, this is the computed ratio of $f_a/F_a + M_{actual}/M_{allowable}$. For concrete it is $M_{actual}/M_{allowable}$.

The weight of the stem will be included only if there is added axial load. For masonry stems, F_a is calculated by considering the wall as unsupported with "K" = 2.0. Since even a very small axial load will activate the unsupported height/slenderness calculation for masonry stems, we suggest you do not enter an axial load unless it is significant (e.g. greater than, say, 500 plf.).

Actual Moment

This is the maximum moment due to the lateral pressures and applied loads above the "Design Height" location entered. Note that when concrete is used, all soil pressures and loads are factored per default Load Factors for evaluation of moments and shears.

Allowable Moment

This is the allowable moment capacity, using working stress for masonry and ultimate strength for concrete. For masonry, both steel and masonry stresses are checked (and half stresses used for no Special Inspection). For concrete strength design, and steel percentage is limited to $0.75 \cdot \rho$ balanced.

Total Force

This is the total lateral force from loads applied above the "Check Design at Height" location entered. Note that when concrete is used, all soil pressures and loads are factored.

Actual Shear

For masonry, the effective thickness based on the actual "d" distance for the moment applied is used, considering partial or full grouting, to determine the unit shear produced by the total lateral force of the stem cross section (equivalent solid thickness is not used). Half stresses are used for no special inspection. Shears are calculated at the "Design height" location entered, not at distance "d" above design height. Concrete stems use a distance "d" x 12" for the shear area, and masonry stems use "jd" x 12" (with proper calculations for partial grouted cells) as the shear area.

Allowable Shear

For masonry, this equals $(f'_m \cdot \text{short term increase}) \cdot \frac{1}{2}$ with a maximum of 50 psi. For concrete, this equals $0.85 \cdot 2 \cdot f'_c \cdot \frac{1}{2}$.

Lap Required If Above / Below [Note: This has been changed from Version 5]

This displays the required lap length if a splice occurs above (or below) the Design Height. They are not cumulative, either make the lap above or below the Design Height for the minimum distance displayed.

The laps required above and below may be different if you are changing from concrete to masonry, or bar size. Suggest read commentary on page 93.

For concrete stems, a Class B lap splice is assumed (see ACI 318-02, 12.15), therefore the lap length is the bar development length x 1.3. No reduction for stress level is permitted for lap splice lengths. Concrete is assumed to be normal weight, and bars not epoxy coated.

For masonry stems, the development length is set at 48 bar diameter, for $F_s = 24,000$ psi and 40 diameters for $F_s = 20,000$ psi. No reduction is made for stress level.

Bond stress is not calculated for concrete, since it is incorporated into the development length formula. For masonry, the program internally calculates it based upon the formula $= M / (j d db)$. It then compares this with the lap length and displays which is critical. Allowable bond stress is 100 psi without special inspection and 200 psi with special inspection, but bond will rarely be critical for masonry.

Bar Embedment into Footing

For the bottom Design Height only (Ht. = 0.00), this displays the required hook bar embedment into the footing. It assumes a bar with a 90 bend and at least a 12 diameter extension. This embedment must be at least 6" or 8 bar diameters.

The minimum footing thickness required is based upon this embedment depth plus the clearance you have specified below the bar (usually 3 inches). If this totals less than the footing thickness you have chosen, a warning message will be displayed.

Note that if the bar extends straight down into a key, it must go the development length, and is not reduced by level of stress. For this condition, refer to the table in Appendix B, and multiply by the displayed Stress Level to get the required embedment.

The program does not reduce embedment length by stress level unless the Reduce Hook Bar Embedment for Stress Level box is checked. This is a code arguable issue.

Footing Tab / Footing Dimensions

This is the screen where you design the footing, by manipulating the heel and toe widths so the actual soil pressure is less than allowable, or you can use the Automatic Footing Design button (described below) to size the footing. This screen also gives you choices for toe and heel reinforcing, or indicates if it is theoretically not required. It also suggests key reinforcing, if applicable.

Criteria	Loads	Stem	Footing	Stability	Description
Footing Dimensions			Key Dimensions & Sliding		
Footing Size			fc	3,000.0 psi	
Toe Width	3.750	\$\$\$\$	Fy	60,000.0 psi	
Heel Width	3.000	ft	Rebar Cover..	In Heel 3.00 in	
Total Width =	6.75 ft		In Toe	3.00 in	
Thickness	15.00	in	Min As Ratio	0.0014	
Center Stem on Footing			Rebar @ Stem Base : #7 @ 16.0		
Toe Reinf options:	#4@ 7.50 in, #5@ 11.75 in, #6@ 16.50 in, #7@ 22.50 in, #8@ 29.75		Use #	0	
Heel Reinf options:	Not req'd, $M_u < S * F_r$		Use #	0	
Key Reinf	#4@ 16.00 in, #5@ 24.75 in, #6@ 35.		Use #	0	
			Max @	0.00 in	
			Max @	0.00 in	
			Max @	0.00 in	
Footing Width Automatic Design					

Toe Width

This is the width of the Toe of the footing, and is measured from the front edge of the footing to the front face of the stem. Can be set to 0.00 for a property line condition. All overturning and resisting moments are taken about the bottom-front edge of the toe.

Heel Width

Distance from front face of stem to back of heel projection. If a dimension is entered that is less than the stem width at the base, the program will automatically reset the heel dimension to at least the

stem width. For a property line at the rear face of the stem, this dimension would be the stem width.

Total Footing Width

The calculated width of the footing, Toe Width + Heel Width.

Footing Thickness

Total footing thickness, NOT including the key depth (if used). For bending and shear design of the footing, the rebar depth "d" is taken as Footing Depth - Rebar Cover - 1/2" (to account for the rebar radius). If footing thickness is inadequate for shear capacity a red warning indicator will appear.

The footing thickness must be greater than the rebar embedment length required for the bottom stem reinforcing + rebar cover. If you enter a dimension less than required for stem bar embedment, a red message will appear at the top of the screen. The program adds the calculated hooked bar embedment from the STEM screen and adds it to the rebar cover you have chosen for the bottom of the footing (usually 3"). This will trigger the red warning. If inadequate thickness, increase the thickness, or change the stem dowels, until this message disappears.

Center Stem on Footing

Clicking this bar will adjust the toe and heel widths you have entered so stem is centered on the footing but overall width remains the same.

f'_c

Enter concrete compressive stress for footing.

F_y

Allowable rebar yields stress to be used for design of footing bending reinforcement.

Rebar Cover in Heel/Toe

Distance from the face of concrete to edge of rebar. The program will add 1/2" to this value and subtract the result from the footing thickness to determine the bending "d" distance.

Minimum As Rebar Ratio

Enter the absolute minimum steel percentage to be used to calculate rebar spacing requirements ($0.0018 A_g$ for $F_y=60,000$ psi). If the % steel required by stress analysis is less than $200/F_y$, the minimum of ($200/F_y$ -or- $1.333 * \text{bending percentage required}$) is calculated and compared with the Minimum As% entered here, and the greater of the two used to calculate rebar spacing requirements.

Rebar at Stem Base

This is a reminder of the size and spacing of the bottom stem reinforcing, to make it easier for you to select toe reinforcing to match (toe reinforcing is usually the bottom stem dowel bars bent toward the toe).

Toe Reinforcing Options

This list gives you choices for reinforcing sizes and spacing for the bottom toe bars. Typically the toe bars are extensions of the stem dowels, which are bent out toward the toe. Therefore, you will probably want only to verify that the stem dowel bar size and spacing do not exceed the selections offered.

Heel Reinforcing Options

This list gives you choices for acceptable sizes and spacing of top heel bars. It is desirable to select a spacing that is modular with the stem dowel bars for ease of construction. Note: The program does not calculate the heel bar development length inward from the back face of the stem (where the moment is maximum). You can refer to Appendix B for development lengths in concrete, which can be adjusted for the stress level in the heel bars. When detailing footing reinforcing it is important to consider and specify development lengths for both toe and heel bars.

Rebar Selections

Use these three entries to pick your toe, heel, and if applicable, key reinforcing. The "Max @" message

tells you the maximum spacing allowed for the bar selected.

[Footing Width Automatic Design]

Clicking this button will cause the program to iterate footing widths until the soil pressure, overturning stability, and sliding stability ratios are acceptable. You can select either a fixed toe or heel distance, or balance the toe and heel dimensions. You can also select whether the resultant must be within the middle third of the footing. After clicking "Design," the widths required will be displayed.

Automatic footing design is not available for Restrained Walls.

Footing Tab / Key Dimensions and Sliding

This screen tells you whether passive soil resistance plus friction resistance is adequate to resist sliding with at least a 1.5 safety factor. If inadequate, you can design a key. If a key is used, the previous footing screen will check whether reinforcing is required by first checking the plain concrete flexural capacity (for computing section modulus, 3" is deducted from the key width per UBC '97). If the key depth to width ratio is less than about 2:1, it's usually adequate.

Criteria	Loads	Stem	Footing	Stability	Description
Footing Dimensions		Key Dimensions & Sliding			
Key Depth	<input type="text" value="24.000"/>	in	Key Width	<input type="text" value="12.000"/>	in
Key Location	<input type="text" value="2.000"/>	ft from front of toe	<input type="button" value="High Width"/>		
Soil over toe to neglect for sliding resistance	<input type="text" value="12.000"/>	in			
Footing/Soil Friction Factor	<input type="text" value="0.300"/>				
% PASSIVE Usable for Sliding Resistance	<input type="text" value="100.0"/>	%			
% FRICTION Usable for Sliding Resistance	<input type="text" value="100.0"/>	%			
Summary of Sliding Forces					
Lateral Force @ Base of Footing	2,961.1 lbs				
less Passive Pressure Force	- 3,202.0 lbs				
less Friction Force	- 2,058.8 lbs				
Added Resisting Force Required	0.0 lbs				
Added Resisting Force Required for 1.5 : 1 Factor of Safety	0.0 lbs				
Sliding Factor of Safety =		1.777 : 1.00			

Key Depth

Depth of the key below the bottom of footing. The bottom of the key is used as the lower horizontal plane for determining the size of the passive pressure block from the soil in front of the footing. Adjust this depth so the sliding safety factor is acceptable, but not less than 1.5. A depth greater than three feet or one-half the footing width is not recommended.

Key Width

Width of the key, measured along the same direction as the footing width. This is usually 12"-14", but generally not less than one-half the key depth so flexural stress in the key is adequate.

Key Location

Enter the distance from the front edge of the toe to the beginning of the key. Do not enter a distance greater than the footing width minus key width.

Align with Stem

Click this button to set front edge of key aligned with front of stem. If the key is then made the same width as the stem, the stem bars could extend down into the key to achieve development.

Soil Over Toe to Neglect for Sliding Resistance

Since the soil over the toe of the footing is usually loose and uncompacted, it may have little or no passive resistance. This entry gives you the option of neglecting any or all of the Height of Soil Over Toe that you had entered in the CRITERIA screen. You can neglect the soil over toe plus the footing thickness, if desired.

Footing/Soil Friction Factor

Enter this friction factor here, which is generally provided by the geotechnical engineer. It usually varies from 0.25 to 0.45.

% Passive Usable for Sliding Resistance

This may be a stated restriction in the geotechnical report. Enter a value from zero to 100%.

% Friction Usable for Sliding Resistance

This may be a stated restriction in the geotechnical report. Enter a value from zero to 100%.

Lateral Pressure @ Base of Footing

This is the total lateral force against the stem and footing which causes the wall to slide and which must be resisted. It is the total active pressure on the heel side less the active pressure on the toe side. The latter will be excluded if you choose to delete it on the OPTIONS screen.

Less Passive Pressure Force

This uses the allowable passive pressure in pcf and the available depth (soil above toe less height to neglect plus footing thickness) to compute the total passive resistance, again multiplied by the percent usable you selected. Weight due to toe surcharge, if applicable, will also be added. If a key is used, the available passive pressure depth will be to the bottom of the key.

Less Friction Force

This is the total vertical reaction multiplied by the friction factor, again multiplied by the percent usable you selected.

Added Resisting Force Required

If this is 0.0 lbs., the forces balance, but there may be no safety factor. Watch the Sliding Factor of Safety for an adequate value (usually 1.5). Add a key as required.

Added Resisting Force Required for 1.5:1 Safety Factor

This is the additional force required to be resisted by a key to achieve a 1.5 safety factor. If zero, no key is required.

Key Reinforcing

If flexural tension is insufficient to resist bending in key, a message will appear indicating reinforcing required. You can vary the width of the key until the message disappears. Or you can manually calculate reinforcing required.

Sliding Factor of Safety

This gives you the ratio of passive and friction resistance to the total lateral force. This should be at

least 1.5.

NOTE : If lateral restraint is provided by an abutting floor slab (by checking the box on the CRITERIA > OPTIONS screen), the sliding factor of safety displays will be deleted, but the "Lateral Force @ Base of Footing" will be displayed for checking restraint adequacy of the slab.

Results Tab - Resisting Moments

This screen presents in tabular form each component contributing to resisting moment, giving weights and lever arms from the front edge of the toe to the centroid of the weight.

Criteria	Loads	Stem	Footing	Stability	Description
Resisting	Overturning	Wall Tilt			
Resisting Moments					
	Force	Distance	Moment		
	Soil Over Hee	1,760.0 lbs	5.75 ft	10,120.0 ft-#	
	Sloped Soil Over He	110.0	6.08	669.2	
	Surcharge Over He	200.0	5.75	1,150.0	
	Adjacent Footing Loa	200.0	5.75	1,150.0	
	Axial Dead Load on Ste	1,000.0	3.75	3,750.0	
	Soil Over Toe	412.5	1.88	773.4	
	Surcharge Over Toe	375.0	1.88	703.1	
	Stem Weight(s)	1,178.3	4.20	4,949.5	
	Earth @ Stem Transitio	61.1	4.58	280.1	
	Footing Weight	1,265.6	3.38	4,271.5	
	Key Weight	300.0	2.50	750.0	
	*Vert. Component	0.0			
	Total Vertical	6,862.6 lbs			
	Resisting Moment			28,566.8 ft-#	
Resisting/Overturning		2.475: 1.00			
* EFP method used. To calculate vertical component, angle of internal friction is back-solved using EFP and Rankine Equation. 37.89degree					
These values are used for soil pressure calculations					
Force =		7,862.6 lbs	Moment =		28,566.8 ft-#

Resisting/Overturning ratio is displayed.

For calculating the vertical component, if checked on the OPTIONS screen, and if the EFP method was chosen, the program will back-solve using the Rankine formula to obtain an equivalent internal friction angle.

The force and moment displayed at the bottom accounts for deduction of effect of vertical component, if box on CRITERIA > OPTIONS box has been checked.

Results Tab / Overturning Moments

This screen presents in tabular form each component acting horizontally to overturn the wall/footing system. The centroid of each force is multiplied by its distance up from the bottom of the footing. The Heel Active Pressure includes the effect of surcharges and water table, if applicable, and its Distance is to the centroid of the total lateral force.

Criteria	Loads	Stem	Footing	Stability	Description
Resisting	Overturning	Wall Tilt			
Overturning Moments					
	Force	Distance	Momen		
Heel Active Pressure	2,783.2lbs	3.67ft	10,225.7 ft-#		
Toe Active Pressure	-88.6	0.75	-66.4		
Adjacent Footing	129.4	4.80	621.5		
Surcharge Over Toe	-71.6	1.13	-80.5		
Load @ Stem Above Soil	45.0	10.75	483.8		
Added Lateral Load	75.0	4.75	356.3		
Totals =		2,872.5 lbs			
		Overturning Moment		11,540.2 ft-#	
		Resisting/Overturning	2.475: 1.00		

The total overturning moment is displayed, and the Resisting/Overturning ratio. The overturning moment is reduced by the toe side active pressure, if this option is selected on the Options screen.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results Tab

Results	Construction	Wall Loading
Soil Loading Results (Service loads)		
Soil Pressure @ Toe		1,989.1 psf
Soil Pressure @ Heel		340.5 psf
Allowable		2,000.0 psf
Total Bearing Load		7,862.6 lbs
...resultant ecc.		9.55 in
Eccentricity within middle third		
Footing Results		
ACI Factored Pressure @ Toe		2,854.2 psf
ACI Factored Pressure @ Heel		488.6 psf
Mu:Design @ Toe		12,222.1 ft-#
Mu:Design @ Heel		3,474.3 ft-#
Heel moment OK using $M < S^*Fr$		
Stem Base Moment Governs TOE Moment		
One-Way Footing Shears...		
Shear @ Toe		36.585 psi
Shear @ Heel		25.239 psi
Allow. Footing Shear		93.113 psi
Stability Ratios		
OTM Ratio		2.475 : 1.00
Sliding Ratio		1.777 : 1.00

Soil Pressure @ Toe and Heel

This is the resulting unfactored soil pressure for both the toe and heel. If the eccentricity is outside the middle third, the heel pressure will show 0.00. (Note: when the resultant is outside the middle-third, the program calculates the toe pressure assuming no "tension" at heel).

Allowable Soil Pressure

This is for your reference as input on the Criteria input Screen

Total Bearing Load

This is the sum of all vertical forces.

Resultant Eccentricity

Distance from center of footing to resultant soil pressure.

Eccentricity Within/Outside Middle Third

The resultant is outside the middle third of the footing width if the eccentricity is greater than one-sixth the footing width. (If outside the middle third, the program computes the toe soil pressure assuming no "tension" at heel.)

ACI Factored Soil Pressure @ Toe and Heel

ACI or AASHTO load factors are applied to all dead and live loads to determine total vertical load for soil pressure used in calculating footing moments and shears. This load is then applied at the same eccentricity calculated for service load soil pressures to yield the actual factored soil pressures for footing design using ultimate strength design principles. Note that since only factored vertical loads are applied at the non-factored resultant eccentricity, a true 1.7 load factor applied to lateral earth pressure is not used for footing design. If resultant vertical load eccentricity were to be calculated

using factored loads, the distance would not truly represent a correct state of stress in the soil. ACI load factors are intended to give conservative results for stress. Calculation of a factored load eccentricity would give soil pressure diagrams that would not always represent the actual soil pressure distribution under the footing, and yield unreasonable results. Factored lateral earth pressure, however, is always used for concrete stem design.

Mu Design @ Toe/Heel

These are the factored (by 1.4) moments at face of stem for toe and heel moments. Since neither can be greater than the stem base moment (factored if concrete stem), the latter may govern. These moments will be reduced if you choose to neglect the upward soil pressure on the Criteria > Options tab.

A message will indicate which controls.

Shear @ Toe and Heel

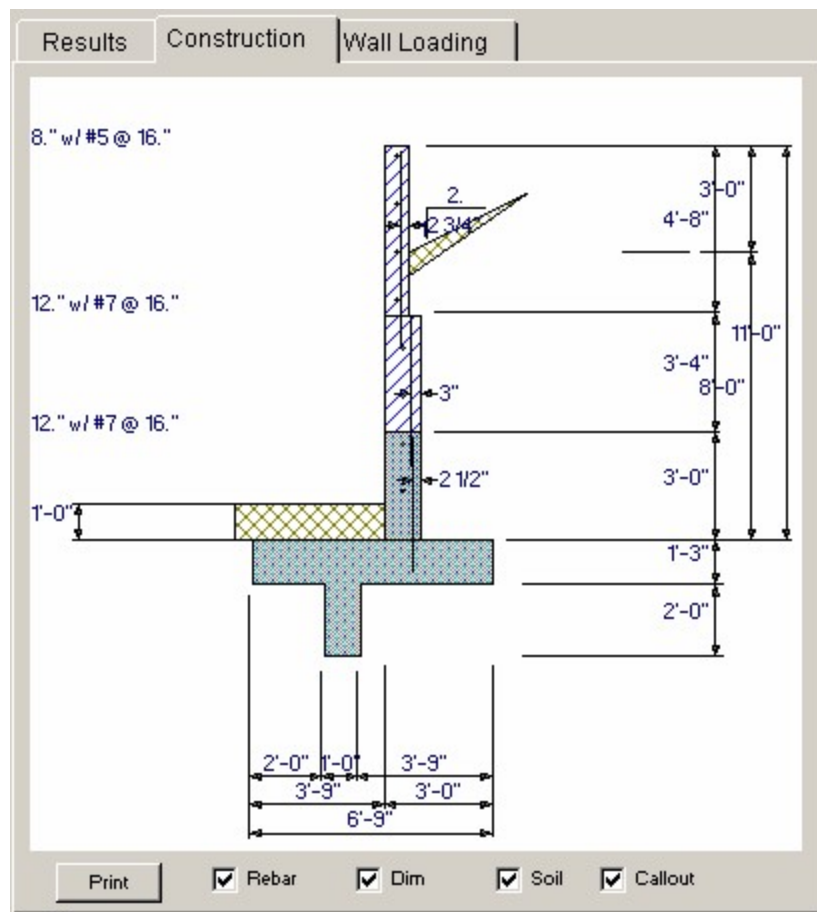
The actual shear is calculated from the one-way action in the footing at a distance "d" (footing thickness - rebar cover) from the toe side of the bottom stem section, and at the face of the stem on the heel side. If "d" is greater than the projecting toe or heel length, then the one-way shear is zero.

Allowable Footing Shear

The allowable unit shear equals $(0.85 * 2 * f'_c)^{1/2}$.

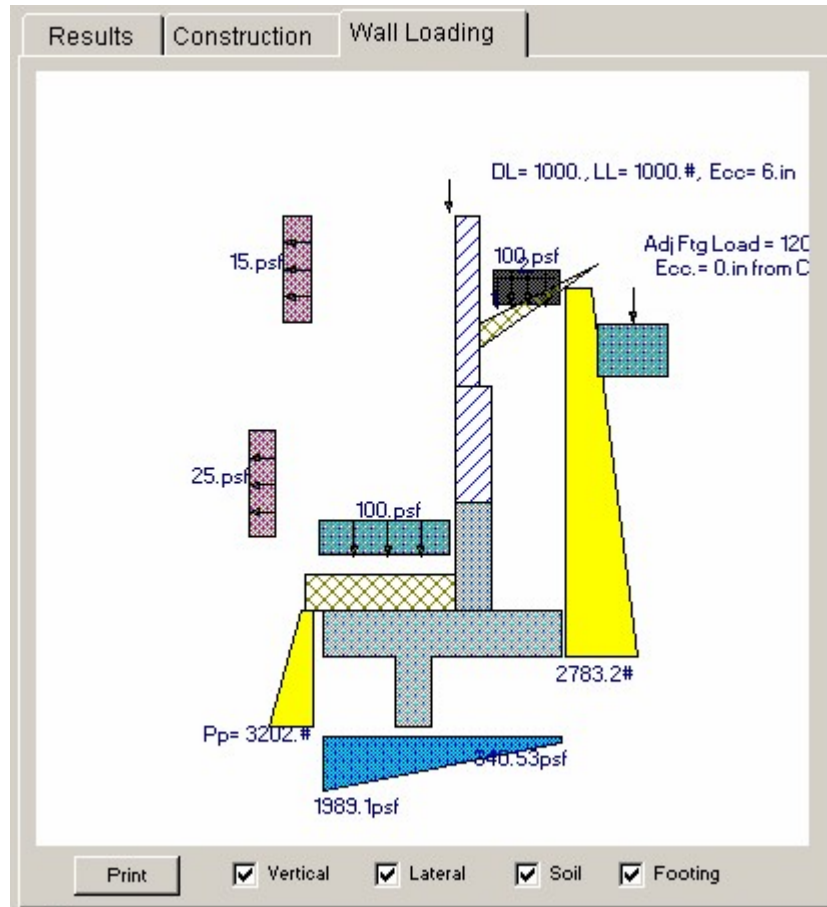
Construction Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Wall Loading Diagram Tab

This tab provides a sketch of the wall and its applied loads. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title : ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 7:16PM, 28 OCT 03
 Description : Collection of example problems
 Scope : All programs in the Structural Engineering Library
 Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Rev: 990000
 User: KVV0600001, Ver: 5.0.0, 10-Sep-2003
 (c)1983-2003 ENERCALC Engineering Software
Cantilevered Retaining Wall Design Page 1
 c:\ec68\examples\enr\Retaining Walls

Description Complex wall, w/ adjacent ftg, axial load, surcharge, etc.

Criteria	
Retained Height	= 8.00 ft
Wall height above soil	= 3.00 ft
Slope Behind Wall	= 2.00 : 1
Height of Soil over Toe	= 12.00 in
Soil Density	= 110.00 pcf
Wind on Stem	= 15.0 psf

Soil Data	
Allow Soil Bearing	= 2,000.0 psf
Equivalent Fluid Pressure Method	
Heel Active Pressure	= 45.0
Toe Active Pressure	= 35.0
Passive Pressure	= 250.0
Water height over heel	= 0.0 ft
Footing Soil Friction	= 0.300
Soil height to ignore for passive pressure	= 12.00 in

Footing Strengths & Dimensions	
f'c =	3,000 psi
Fy =	60,000 psi
Min. As %	= 0.0014
Toe Width	= 3.50 ft
Heel Width	= 3.00
Total Footing Width	= 6.50
Footing Thickness	= 15.00 in
Key Width	= 12.00 in
Key Depth	= 24.00 in
Key Distance from Toe	= 2.00 ft
Cover @ Top	= 3.00 in @ Btm = 3.00 in

Surcharge Loads	
Surcharge Over Heel	= 100.0 psf
Used To Resist Sliding & Overturning	
Surcharge Over Toe	= 100.0 psf
Used for Sliding & Overturning	

Lateral Load Applied to Stem	
Lateral Load	= 25.0 #/ft
...Height to Top	= 5.00 ft
...Height to Bottom	= 2.00 ft

Adjacent Footing Load	
Adjacent Footing Load	= 1,200.0 lbs
Footing Width	= 2.00 ft
Eccentricity	= 0.00 in
Wall to Ftg CL Dist	= 4.00 ft
Footing Type	Line Load
Base Above/Below Soil at Back of Wall	= -1.5 ft

Axial Load Applied to Stem	
Axial Dead Load	= 1,000.0 lbs
Axial Live Load	= 1,000.0 lbs
Axial Load Eccentricity	= 6.0 in

Design Summary	
Total Bearing Load	= 7,767 lbs
...resultant ecc.	= 10.54 in
Soil Pressure @ Toe	= 2,164 psf NG
Soil Pressure @ Heel	= 226 psf OK
Allowable	= 2,000 psf
Soil Pressure Exceeds Allowable!	
ACI Factored @ Toe	= 3,106 psf
ACI Factored @ Heel	= 325 psf
Footing Shear @ Toe	= 36.9 psi OK
Footing Shear @ Heel	= 25.2 psi OK
Allowable	= 93.1 psi
Wall Stability Ratios	
Overturning	= 2.34 OK
Sliding	= 1.77 OK
Sliding Calc (Vertical Component NOT Used)	
Lateral Sliding Force	= 2,872.5 lbs
less 100% Passive Force	= - 3,202.0 lbs
less 100% Friction Force	= - 2,030.2 lbs
Added Force Req'd	= 0.0 lbs OK
...for 1.5 : 1 Stability	= 0.0 lbs OK

Stem Construction	Top Stem			2nd	3rd
	Ratio > 1.0	Stem OK	Stem OK		
Design height	ft = 6.33	3.00	0.00		
Wall Material Above "H"	= Masonry	Masonry	Concrete		
Thickness	= 8.00	12.00	12.00		
Rebar Size	= # 5	# 7	# 7		
Rebar Spacing	= 40.00	16.00	16.00		
Rebar Placed at	= Center	Edge	Edge		
Design Data					
fb/fB + fa/fa	= 9.878	0.622	0.682		
Total Force @ Section	lbs = 175.7	954.8	3,338.2		
Moment...Actual	ft-# = 1,234.1	2,910.1	12,222.1		
Moment...Allowable	ft-# = 129.9	6,477.9	18,468.0		
Shear...Actual	psi = 4.9	10.0	29.1		
Shear...Allowable	psi = 34.7	38.7	93.1		
Bar Develop ABOVE Ht.	in = 12.83	42.00	37.38		
Bar Lap/Hook BELOW Ht.	in = 25.00	37.38	8.73		
Wall Weight	psf = 75.0	118.0	145.0		
Rebar Depth 'd'	in = 3.81	9.00	9.56		
Masonry Data					
f'm	psi = 1,05	1,500			
Fs	psi = 1,687	24,000			
Solid Grouting	= Yes	Yes			
Special Inspection	= Yes	Yes			
Modular Ratio 'n'	= 366.64	25.78			
Short Term Factor	= 3.378	1.000			
Equiv. Solid Thick.	in = 7.60	11.62			
Masonry Block Type	= Lightweight				
Concrete Data					
f'c	psi =	3,000.0			
Fy	psi =	60,000.0			

Footing Design Results		
	Toe	Heel
Factored Pressure	= 3,106	325 psf
Mu' : Upward	= 0	0 ft-#
Mu' : Downward	= 0	3,474 ft-#
Mu: Design	= 12,222	3,474 ft-#
Actual 1-Way Shear	= 36.94	25.24 psi
Allow 1-Way Shear	= 93.11	93.11 psi
Toe Reinforcing	= None Spec'd	
Heel Reinforcing	= None Spec'd	
Key Reinforcing	= None Spec'd	

Other Acceptable Sizes & Spacings
 Toe: #4 @ 7.50 in, #5 @ 11.75 in, #6 @ 16.50 in, #7 @ 22.50 in, #8 @ 29.75 in, #9 @ 37
 Heel: Not req'd, Mu < S * Fr
 Key: #4 @ 16.00 in, #5 @ 24.75 in, #6 @ 35.

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems **Job #** 97-000001
Dsgnr: MDB **Date:** 7:16PM, 28 OCT 03
Description: Collection of example problems
Scope: All programs in the Structural Engineering Library
 Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Rev: 580000
 User: RW00000001 Ver 5.0.0, 10-Sep-2003
 (C)1983-2003 ENERCALC Engineering Software **Cantilevered Retaining Wall Design** Page 2
 c:\e65\examples.eas\Retaining Walls

Description Complex wall, w/ adjacent ftg, axial load, surcharge, etc.

Summary of Overturning & Resisting Forces & Moments

ItemOVERTURNING.....			=RESISTING.....		
	Force lbs	Distance ft	Moment ft-#		Force lbs	Distance ft	Moment ft-#
Heel Active Pressure	= 2,783.2	3.67	10,225.7	Soil Over Heel	= 1,760.0	5.50	9,680.0
Toe Active Pressure	= -88.6	0.75	-66.4	Sloped Soil Over Heel	= 110.0	5.83	641.7
Surcharge Over Toe	= -71.6	1.13	-80.5	Surcharge Over Heel	= 200.0	5.50	1,100.0
Adjacent Footing Load	= 129.4	4.80	621.5	Adjacent Footing Load	= 204.3	5.50	1,123.4
Added Lateral Load	= 75.0	4.75	356.3	Axial Dead Load on Stem	= 1,000.0	3.50	3,500.0
Load @ Stem Above Soil	= 45.0	10.75	483.8	Soil Over Toe	= 385.0	1.75	673.8
Seismic Load	=			Surcharge Over Toe	= 350.0	1.75	612.5
Total	= 2,872.5	O.T.M. =	11,540.2	Stem Weight(s)	= 1,178.3	3.95	4,654.9
Resisting/Overturning Ratio	=	2.34		Earth @ Stem Transitions	= 61.1	4.33	264.9
Vertical Loads used for Soil Pressure	=	7,767.4 lbs		Footing Weight	= 1,218.7	3.25	3,960.9
Vertical component of active pressure, NOT used for soil pressure	=	26,962.0		Key Weight	= 300.0	2.50	750.0
				Vert. Component	=		
				Total =	6,767.4 lbs	R.M. =	

4.2 Restrained Wall

This program provides calculation procedures necessary to perform complete design and analysis of a propped-cantilevered retaining wall.

The retaining wall may be loaded with any of the following load combinations :

- Any angle of sloped backfill.

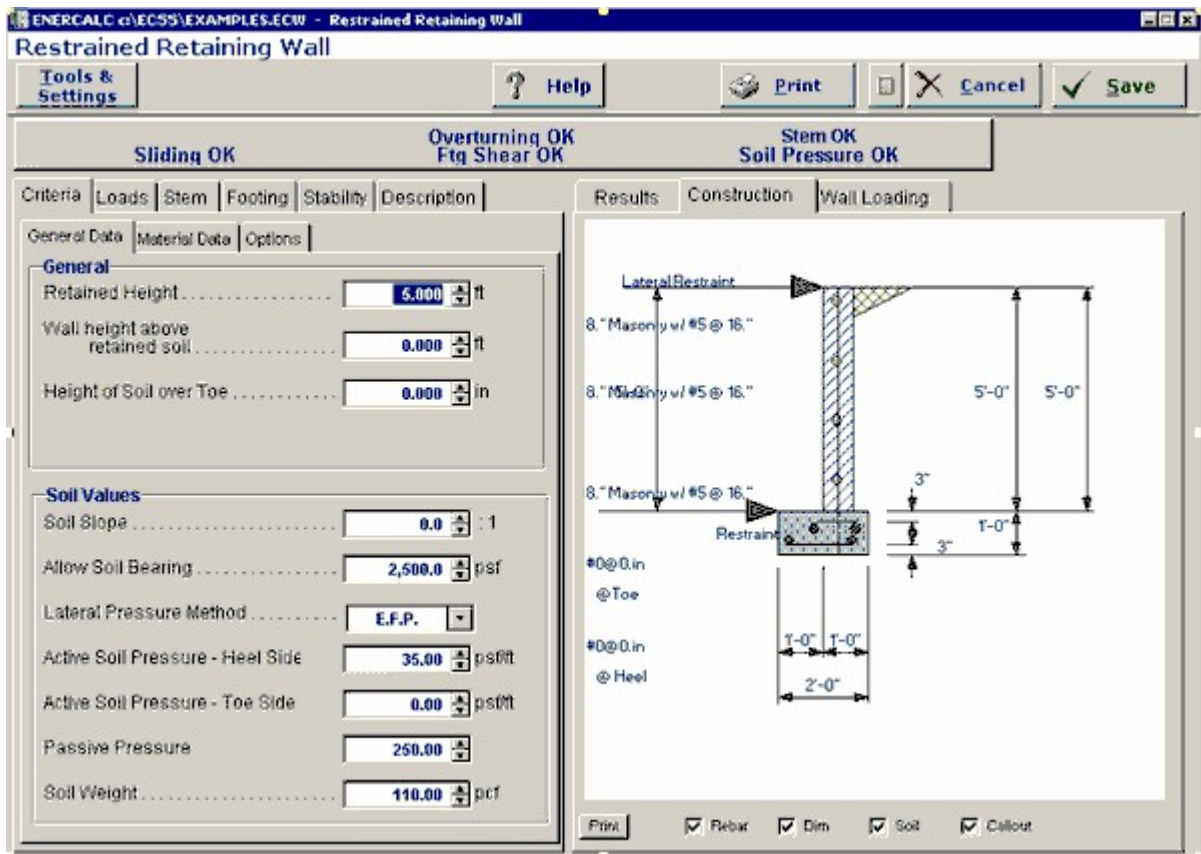
- Surcharge loading above heel or toe.
- Eccentric axial dead and live load on stem.
- Lateral and vertical load from an adjacent footing.
- Wind or seismic force on projecting portion of stem.
- An additional uniform lateral load may be applied to the wall.

The following overall dimensions can be specified:

- Retained height and top support height
- Toe and heel dimension.
- Wall extension above retained height.
- Footing key depth, width, and location.
- Soil height over the toe.

The following stability checks are performed:

- Total overturning and resisting moment.
- Optional Inclusion of vertical active pressure on the rear face of the wall to resist overturning.
- Sliding resistance using both passive and active pressure.
- Both heel and toe of the footing are designed as follows:
- Toe Design - Find actual moment at stem face, check required minimum reinforcing, list rebar choices, and check one-way shear.
- Heel Design - Find moment at stem face, check required minimum reinforcing, list rebar choices and check one-way shear. User may neglect upward soil pressure for conservative design.



Basic Usage

- Entering Soil Data specifies the lateral earth pressures applied to the wall. Active Pressure will be used on over toe and/or heel unless Slope is non-zero. If this is the case, then the soil is sloped and Slope Pressure will be used behind the wall to generate lateral loads. Maximum Pressure can be entered to instruct the program to limit the lateral pressure intensity. (The pressure diagram then becomes uniform). Passive Pressure will be used for the full depth of soil in front of the wall to resist sliding. Soil Density will be used for soil weight, and Soil Height Over Toe will be used to define passive pressure height, vertical load, and will create an active pressure resisting overturning.
- You can apply two additional vertical Loads: an Axial Load to the top of the stem (with optional eccentricity), and Toe and Heel Surcharges. If the heel surcharge is permanent, you can specify that it Should Be Used To Resist Overturning.
- In addition to the lateral loads created by the soil above the footing, you can apply additional Lateral Loads to the wall. Enter a Lateral Loads Acting on the Stem Above Soil when your wall will extend above the soil, such as a screen or guard wall. Impact and bracing loads can be applied to the wall using the Additional Lateral Load item, letting you specify a load intensity and length. You can also enter an Adjacent Footing Load, by specifying the magnitude of load and position relative to the rear of the topmost stem section.

- The Wall and Footing Data section is used to specify the retained height, stem height above soil, and footing dimensions. Zero entries are permitted for the key and either toe or heel width. While using the program, you can easily change these values often and recalculate [F9] to determine soil pressures, overturning stability, and sliding stability.
- The critical footing wall design values are given in the Summary area, where you can review calculated results and then modify the wall and footing data as required.
- The program will perform a Sliding Check when you enter Footing/Soil Friction coefficients, and can Neglect a certain height of soil, if the soil in front of the wall is non-compacted.
- By simply entering the concrete strength, steel strength, and minimum steel percentage the program will provide a full Footing Analysis and Rebar List.
- Stem Design can be performed for up to five independent sections of the wall. By specifying Wall Construction Type, Design Height, and Wall Thickness and Reinforcing, each stem section can be easily refined for an optimum design.
- The Summary of Overturning and Resisting Moment table should be reviewed if you have any questions on how the vertical and lateral loads are being applied to the wall.
- When you are satisfied with the wall, Print or Save the current worksheet, choose Reset to start another wall design, or use the Access Menu to choose another program.

Unique Features

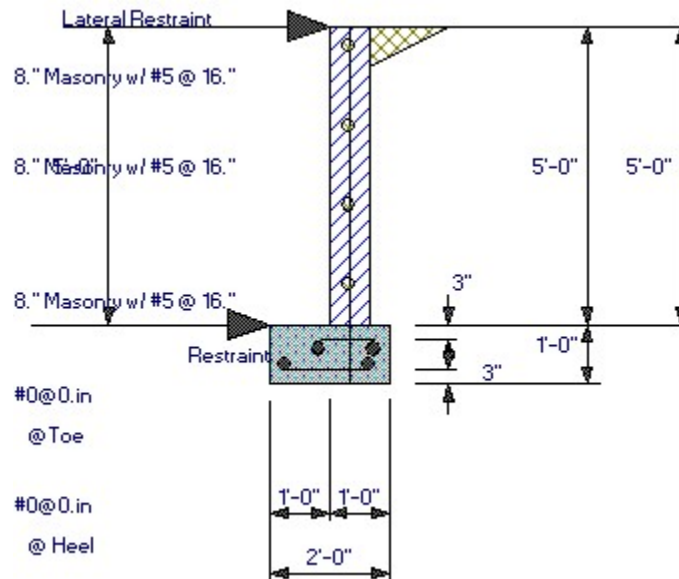
- Slope of backfill may be varied from flat to 45 degrees.
- Either a concrete or masonry stem can be specified. When concrete is chosen, the wall thickness, rebar size, and location is used to calculate the minimum spacing for the rebar. When masonry is specified, the option of special inspection is entered in addition to the above values, and the maximum rebar spacing is calculated at 8" modules.
- The program has the unique ability to design screen walls for conditions where the wall extends a distance above the soil which is much greater than the retained height.

Assumptions & Limitations

- Both active and passive pressures are applied as Equivalent Fluid Pressures.
- Friction coefficient is assumed to be applicable for both friction only and friction combined with passive pressure cases.
- Design for bending reinforcement in Toe and/or Heel of footing is calculated using $d = \text{thickness} - 3"$.
- If surcharge exists above the Toe or Heel, the soil height over those areas will be increased (internally) by the ratio of Surcharge/Soil Density.
- All concrete design is based on ACI Ultimate Strength Design.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Data Tab

Criteria	Loads	Stem	Footing	Stability	Description
General Data Material Data Options					
General					
Retained Height	5.000 ft				
Wall height above retained soil	0.000 ft				
Height of Soil over Toe	0.000 in				
Soil Values					
Soil Slope	0.0 : 1				
Allow Soil Bearing	2,500.0 psf				
Lateral Pressure Method	E.F.P.				
Active Soil Pressure - Heel Side	35.00 psf/ft				
Active Soil Pressure - Toe Side	0.00 psf/ft				
Passive Pressure	250.00				
Soil Weight	110.00 pcf				

Retained Height

This is the height of retained earth measured from top of footing to the top of soil behind the stem (over the heel). When the backfill is sloped, the soil will slope away and upwards from this height. The actual retained height used for overturning and soil pressure calculations will be the retained height projected at the vertical plane of the back of the heel, but for stem moments, no such increase will be made. Using the spin-buttons you can vary this in 3-inch increments (you can type in any number). After each entry you can press the tab key to advance to the next entry, or use your mouse to position the cursor.

Wall Height Above Retained Soil

Use this entry to specify if the wall extends above the retained height. This entry is typically used to define a "screen wall" projection above the soil retained. This extension can be used as a weightless "Fence" or a concrete or masonry stem section without any soil retained behind it. You can enter wind load on this projection using the entry "Load @ stem above soil" on the "Loads" tab. We'll handle the fence when we get to the STEM design screen.

Height of Soil Over Toe

Measured from the top of footing to top of soil, this may vary from a few inches to a few feet (it is measured in inches) depending upon site conditions. It is used to calculate passive soil pressure depth (considering "Ht. to Neglect" on "Sliding" tab). This soil can also be used to calculate an active pressure to reduce overturning; this is a choice on the Options Screen, and can have significant effect if the footing is well below grade.

Water Table Height Over Footing

If you want to design for a water table condition, enter the maximum height from top of footing to

water table level. The program will then compute the added pressures for saturated soil on the heel side of the footing, including buoyancy effect, to calculate increased moments and shears on the stem, and overturning. Do not enter a height greater than the retained height, nor a liquid other than water.

Soil Slope

You may enter any backfill slope behind the wall. Use the drop-down menu or type the slope ratio as Horiz/Vert. The soil must be level or slope upward. Negative backfill slopes (grade sloping downward, away from the wall) are not allowed.

The program will use this slope to 1) include the weight of a triangular wedge of soil over the heel as vertical load, and 2) compute overturning based upon an assumed vertical plane at the back face of the footing extending from the bottom of the footing to ground surface - a steeper slope will result in a higher overturning moment. We suggest not using a slope steeper than 1.5 to 1.0 unless approved by the geotechnical engineer. The program will not accept a backfill slope steeper than the angle of internal friction.

Allowable Soil Bearing

The maximum allowable soil bearing pressure for static conditions. Using the spin buttons you can increment in 50 psf steps. Usual values for this vary from 1,000 psf to 4,000 psf or more.

Lateral Pressure Method

Here you can choose between E.F.P. or Rankine formula or Coulomb formula. EFP means "Equivalent Fluid Pressure," where you can enter a lateral soil pressure in psf per foot of depth. "Rankine" or "Coulomb" instructs Retain Pro to use the Rankine or Coulomb Method to calculate active and passive soil pressures using an entered angle of internal friction for the soil. When Rankine or Coulomb is chosen, the $K_a \cdot \text{Density}$ value for active pressure is computed.

Active Soil Pressure - Heel Side (EFP Method Chosen)

Active Pressure: $K_a \cdot \text{Gamma}$ (Rankine or Coulomb Method Chosen)

Enter the equivalent fluid pressure (EFP), or the angle of internal friction if Rankine or Coulomb is chosen, for the soil being retained that acts to overturn and slide the wall toward the toe side. This pressure acts on the stem for stem section calculations, and on the total footing+wall+slope height for overall stability and soil pressure calculations.

Commonly used values, assuming an angle of internal friction of 34, are 30 pcf for a level backfill; 35 pcf for a 4:1 slope; 38 pcf for a 3:1 slope; 43 pcf for a 2:1 slope; and 55 pcf for a 1.5:1 slope. These values are usually provided by the geotechnical engineer. If the Rankine or Coulomb method had been chosen, these values will be computed using those formulas.

When the retained soil is sloped, a vertical component of the lateral earth pressure over the heel can be applied vertically downward in the plane of the back of the footing. You can choose to apply this force for overturning resistance, sliding resistance, and/or for soil pressure calculations, by checking the boxes on the CRITERIA > Option screen.

Angle of Internal Friction (Rankine or Coulomb Method Chosen)

This value is entered in degrees and is the angle of internal friction of the soil. This value is usually provided by a geotechnical engineer from soils tests, but can also be found in reference books or building codes for various typical soil classifications. This value is used along with Soil Density within the standard Rankine and Coulomb equations to determine " K_a " and " K_p " multipliers of density to give active and passive soil pressure values.

Active Soil Pressure - Toe Side

If the EFP method is chosen, enter the active pressure to be used on the toe side of the wall. This active pressure is used along with the "Soil Height over Toe" value (entered on the Sliding tab) to calculate a stabilizing soil force on the wall. This front side of the wall is assumed to be level.

When either the Rankine or Coulomb method is chosen, the angle of internal friction is used in the Rankine formula with an assumed level toe-side slope.

The active pressure from soil over the toe partially counteracts the heel-side active pressure for overturning calculations.

Passive Pressure (EFP Method Chosen)

Passive Pressure: $K_p * \gamma$ (Rankine or Coulomb Method Chosen)

This is the resistance of the soil in front of the wall to being pushed against to resist sliding. Its value is in psf per foot of depth (pcf). For the E.F.P. method, you input this value, which is usually obtained from the geotechnical engineer. If the Rankine or Coulomb method is chosen, it will be computed and entered for you. Its value usually varies from 100 pcf to about 350 pcf.

Soil Density

Enter the soil density for all earth above the toe and heel of the footing. This weight is used to calculate overturning resistance forces and soil pressures using the weight of the soil block over the projecting toe and heel of the footing. When surcharges are applied over the soil, the surcharges are transformed to equivalent uniform lateral loads acting on the wall by the ratio force = (Surcharge/Density)*Lateral Load. Input this value in lbs. per cubic foot. Usual values are 110 pcf to 120 pcf.

Material Data Tab

This screen allows you to change properties of masonry and concrete. It also allows you to decide what load factor (1.4 or 1.7) to use for factored soil pressure attributable to dead loads.

Criteria | Loads | Stem | Footing | Stability | Description

General Data | Material Data | Options

Masonry

Concrete block type **Normal Weight** ▾

Factor applied to f_m
for calculation of E_m **750.0**

Multiplier applied to
wall weight from tables **1.000**

Concrete

Concrete Weight **145.00** ▲ ▾ pcf

ACI Factored Soil Pressure

Load Factor Used For Upward Factored Soil Pressure...
Calculate using 1.4*DL + 1.7*LL ▾

For Masonry

Concrete Block Type

This allows you to select Lightweight, Medium weight, or Normal weight concrete masonry units.

Factor Applied to f'_m for Calculation of E_m

The modulus of elasticity for masonry is $750 f'_m$ (UBC '97 2106.12.1). This entry allows you to select a multiplier other than 750.

Multiplier Applied to Wall Weight from Tables

This entry allows you to increase or decrease the internal default values of stem weights, as displayed on the STEM screen.

For Concrete

Stem concrete weight

This is usually 145-150 pcf, but may be changed with this entry.

Footing concrete weight

This option is necessary since if there is any buoyancy effect, this will reduce the effective weight of the footing concrete.

ACI Factored Soil Pressure

This gives you two choices for computing the factored moment in the toe. Select either a 1.7 load factor for both dead load and pressure attributable to live load and lateral soil pressure on the wall. Alternatively, and less conservative, use a load factor of 1.4 for dead load (footing and superimposed earth) and 1.7 for live load and upward soil pressure attributable to lateral soil pressure.

Options Tab

This screen is critical to your design, since many subsequent calculation results will be affected. Review and check these boxes carefully.

Criteria	Loads	Stem	Footing	Stability	Description
General Data Material Data Options					
Use AASHTO Load Factors ? <input type="checkbox"/>					
Slab is present to resist all sliding forces <input checked="" type="checkbox"/>					
Use these items when your surcharge may not be applied 100% of the time to resist the forces.					
Use TOE Surcharge To Resist Sliding & Overturning ? <input type="checkbox"/>					
Use HEEL Surcharge To Resist Sliding & Overturning ? <input type="checkbox"/>					
Use this item to ignore the upward soil pressure under the heel when calculating heel moments & shears.					
Neglect Upward Pressure at Heel ? <input checked="" type="checkbox"/>					
Toe Active Pressure Used... To Resist Overturning					
Use these choices to select when to use the vertical compo of active lateral soil pressure.					
Use for Soil Pressure? <input type="checkbox"/>					
Use for Sliding Resistance ? <input type="checkbox"/>					
Use for Overturning Resistance ? <input type="checkbox"/>					

Slab is Present to Resist all Sliding Forces

Check this box when a slab is in front of the wall to resist lateral sliding. This negates sliding concerns (but check the slab if necessary). For restrained wall footings, it deletes the lateral force (base stem reaction) applied to the top of the footing, puts "not applicable" in the sliding ratio display, and dims the sliding entries on the FOOTING > KEY DIMENSIONS AND SLIDING sub-tab screen. The slab restraint is assumed to be at the top of the footing and the program does not allow it to be placed higher-if this condition occurs, append your printout with hand-calcs,

Use Toe Surcharge to Resist Sliding and Overturning

Checking this box will include the weight of soil overburden on the toe to resist overturning and add to its weight for frictional resistance.

Use Heel Surcharge to Resist Sliding and Overturning

Checking this box will include heel surcharge. If surcharge is live load and its use would be non-conservative, don't check this box.

Neglect Upward Pressure at Heel

For heel calculations you may choose to neglect the upward soil pressure, typically resulting in greater heel moment. If this box is checked the Mu for upward loads will be zero.

Toe Active Pressure Used

Checking this box will apply the toe side active pressure to reduce overturning moment and reduce sliding force to a net sliding force to be resisted.

Choices for Use of Vertical Component of Active Pressure

The vertical component of the lateral pressure is applied at a vertical plane at the back of the footing.

You can optionally use this to resist overturning, sliding, or for soil pressure calculations. (For the latter it can make a considerable difference). Checking these boxes applies the options. For a level backfill, this option will back-solve the EFP method to find the equivalent internal friction angle, then apply this vertical component equal to \tan . If either the Rankine or Coulomb method had been chosen, this

vertical component would be tangent of $\frac{\phi}{2}$.

Note that most texts suggest using the vertical component only to resist overturning. For a level backfill these options are usually not used.

Loads / Vertical Loads Tab

Additional loads on the wall are entered on these sub-tabs.

The screenshot shows a software window with several tabs: 'Criteria', 'Loads', 'Stem', 'Footing', 'Stability', and 'Description'. The 'Loads' tab is active, and within it, the 'Vertical Loads' sub-tab is selected. Under 'Vertical Loads', there are two sub-sections: 'Surcharges' and 'Axial Load Applied to Top of Stem'. The 'Surcharges' section has two input fields: 'Surcharge over Toe' and 'Surcharge Over Heel', both with a value of 0.00 and units of psf. The 'Axial Load Applied to Top of Stem' section has three input fields: 'Axial Dead Load', 'Axial Live Load', and 'Axial Load Ecc.', with values of 0.0, 0.0, and 0.00 respectively, and units of lbs, lbs, and in.

Surcharge Over Toe

If other loads are imposed directly above the toe (such as a slab, storage, or moving load), these may be entered here (you have already entered the height of the soil over toe). This surcharge is divided by soil density and multiplied by active pressure to calculate an equivalent lateral load. This surcharge is used to calculate soil pressure. You can use this surcharge to resist sliding and overturning by clicking the box on the CRITERIA > Options sub-tab.

Surcharge Over Heel

This surcharge is considered uniformly applied to the top surface of the retained soil (over the heel). It may be entered whether or not the ground surface is sloped, but is always taken as a vertical force. This surcharge is divided by the soil density and multiplied by the Active Pressure to create a uniform lateral load applied to the wall. You can use this surcharge to resist sliding and overturning by clicking the box on the CRITERIA > Options sub-tab.

Axial Loads Applied to Top of Stem

These loads are considered uniform load along the length of the wall. They are applied to the top of the topmost stem section and effect the design of masonry stems only. The dead and live loads are used to calculate stem design values and factored soil reaction pressures used for footing design. Only the dead load is used to resist overturning and sliding of the retaining wall.

Axial Load Eccentricity

This is the eccentricity of the axial load with respect to the centerline of the uppermost stem section. The eccentricity moves the load toward the toe, causing bending moments that are additive to those caused by the lateral soil pressure over the heel (negative eccentricities are not accepted).

Adjacent Footing Load

This entry gives you the option of placing a footing adjacent and parallel to the back face of the wall, and have its effect on the wall included in both the vertical and horizontal forces on the wall and footing. Refer to the General Reference Diagram for locations where input measurements should be taken.

For a "Line Load" the load entered is the total load per foot parallel to the wall (not lbs. per sq. ft).

If the adjacent footing is specified as "Square Footing" (not line load), the load entered should be the adjacent footing load divided by its dimension parallel to the wall, giving a pounds per lineal foot value, as for a continuous (line) footing.

A Boussinesq analysis is used to calculate the vertical and lateral pressures acting on the stem and footing. The program uses an assumed Poisson ratio of 0.3. (See Foundation Analysis and Design, 5th Edition, by J. E. Bowles, McGraw-Hill, pages 629-639)

Use of the Adjacent Footing may not be applicable if the horizontal distance from back face to stem to closest edge of adjacent footing is greater than the distance from top of wall footing to bottom of Adjacent Footing (i.e. outside an assumed line of influence).

When the Boussinesq analysis is used, the program may require additional computing time, depending upon the speed of your computer. To avoid this delay (which occurs any time any entry is changed) we suggest you use a vertical load of zero until your data entry is nearly finalized. Then enter the actual footing load and modify your final values.

Suggestion: For adjacent truck or highway loading, it may be preferable to use a heel surcharge (uniform) of 250 psf (or more) instead of treating it as an "adjacent footing."

Do not use this feature if the adjacent footing load is farther from the stem than the retained height, less the depth of the adjacent footing below the retained height, since at this distance it will not have significant effect on the wall.

Footing Width

Width of the adjacent footing measured perpendicular to the wall. This is necessary to create a one-foot long by Width wide area over which the load is applied.

Footing Eccentricity

This entry is provided in case the soil pressure under the adjacent footing is not uniform. Enter the eccentricity of the resultant force under the adjacent footing from the centerline of the footing. Positive eccentricity is toward the toe, resulting in greater pressure at the side of the adjacent footing closest to the stem. The program will use the vertical load and eccentricity and create a trapezoidal pressure distribution under the adjacent footing for use with the Boussinesq analysis of vertical and lateral pressures.

Wall to Footing Centerline Distance

Distance from the center of the adjacent footing to the back face of the stem at the retained height.

Footing Type

This drop down menu selection allows you to enter either an isolated footing using the "Square Footing" selection, or a continuous footing using the "Line Load" selection.

Base Above/Below Soil at Back of Wall

Use this entry to locate the bottom of the footing with respect to the Retained Height. Entering a negative number places the footing below the soil. A positive entry would typically only be used when the soil is sloped and the footing resides "uphill". To insert a negative number, first type the number then press the "-" (minus) sign.

Note: If the "Adjacent Footing" is another retaining wall at a higher elevation, the Boussinesq analysis may be used for the vertical load applied to the soil from the wall, however the design must also consider the lateral (sliding) loads from that adjacent wall. This load could be applied as "Added Lateral

Load", however this is at the discretion of the designer and is not within the scope of the program. Caution is urged for this condition. See discussion in the companion book: Basics of Retaining Wall Design.

Loads / Lateral Loads Tab

The screenshot shows a software window with tabs for 'Criteria', 'Loads', 'Stem', 'Footing', 'Stability', and 'Description'. The 'Loads' tab is selected, and within it, the 'Lateral Loads' sub-tab is active. The main area contains the following fields:

- Load @ stem above soil**: A numeric input field with a value of 0.00 and units of psf.
- Added Lateral Load on Stem**: A section containing three fields:
 - Lateral Load**: A numeric input field with a value of 0.00 and units of #/ft.
 - ...Height to Top**: A numeric input field with a value of 0.00 and units of ft.
 - ...Height to Bottom**: A numeric input field with a value of 0.00 and units of ft.

Load @ Stem Above Soil

This load (typically a wind load) will be applied to that part of the stem projecting above the retained height defined by the entry "Wall height above retained soil." It is used to calculate overturning moment and shear, stem design moment and shear, and soil pressures. Customary values are 10 psf or higher. Only a positive "+" value can be entered (i.e., the force may only be applied in a direction to add overturning, in the direction of the active soil pressure).

Added Lateral Load

This input allows you to specify an additional uniformly distributed lateral load applied to the stem. You can use it to apply a seismic load to the wall, an additional uniform lateral load due to soil pressure, or apply a short but intense load due to impact of a car or similar force (this case can be modeled by separating the "Height to Bottom" and "Height to Top" by just one foot, and using an "Added Lateral Load" equal to the total added force). This load is factored by 1.7 to calculate concrete moments and shears.

Height to Top

This dimension defines the upper limit of the added lateral load measured from the top of the footing. Do not enter a dimension higher than the top of the wall ("retained height" plus "Wall height above retained soil").

Height to Bottom

This dimension defines the beginning (or bottom) of the added lateral load measured from the top of the footing.

Stem Tab

The layout of this screen will change depending upon whether you previously chose a conventional cantilevered wall, a tapered stem wall (earth side battered), or a gravity wall. This screen is for a straight stem non-battered wall.

Criteria	Loads	Stem	Footing	Stability	Description
				fm	1,500.0 psi
Material	Masonry			Fs	24,000.0 psi
Support Height	5.000	ft			
Thickness	3	in		Inspection	<input type="checkbox"/> Solid Grou
Fix Stem @ Base ?	<input checked="" type="checkbox"/>			Short Terr	1
Stem Design...					
	@ Top Support	Mmax Btwn Ends	@ Stem Base		
Ht. Above Footing	5.00 ft	2.77 ft	0.00 ft		
Rebar Depth 'd'	3.81 in	3.81 in	3.81 in		
Rebar Size	# 5	# 5	# 5		
...Location	<input checked="" type="radio"/> Cente <input type="radio"/> Edge	<input checked="" type="radio"/> Cente <input type="radio"/> Edge	<input checked="" type="radio"/> Cente <input type="radio"/> Edge		
Rebar Spacing	16	16	16		in
	(n/a)	Toe Side	Earth Side		
Actual Moment	0.0 ft-#	130.4 ft-#	-291.7 ft-#		
Allowable Momer	619.4 ft-#	619.4 ft-#	619.4 ft-#		
Status -->>	Stem OK	Stem OK	Stem OK		
Rebar Lap Req'd	25.00 in	25.00 in			
Rebar Hook Develop Length into footing			6.00 in		
Shear @ Section	0.00 lbs		350.00 lbs		
Actual Stress	0.000 psi		8.744 psi		
Allowable Stress	19.365 psi		19.365 psi		

Wall Type

If Restrained Stem is selected, you may have a lateral support (such as an abutting roof, slab-on-grade over backfill, or tiebacks). The lateral support should be near the top of the wall, although some extension of the wall above the support is permitted. You have the option of fixing the base (as for a cantilevered wall) or assuming it pinned. Intermediate degrees of fixity are not permitted. The program will compute moments, shears, and stresses at three locations: base (negative moment if fixed; zero moment if pinned), maximum positive moment between base and support, and at the point of support.

Material

Select Masonry or Concrete. Only one material can be used, and must be of constant thickness.

Support Height

Use the spin buttons (or type the value) for height from base to level of support. To check the overall wall height that you had input (retained height plus height above soil) just click the CRITERIA tab.

Thickness

The program only permits a constant thickness throughout the height of the wall.

Use the spin button (or type) the choice for thickness. If Masonry was chosen, the drop down menu will give you modular choices.

Fix Stem @ Base

Clicking this box will check footing and stem for 100% fixity at base. If unchecked, pin condition will be assumed.

f'_m or f'_c

Enter choice for masonry or concrete.

 F_s or F_y

Enter choice for masonry or concrete.

Rebar Cover

This appears if a concrete stem is chosen and lets you enter desired cover on toe and earth side.

Inspection

This is applicable to masonry stems only, and if checked, the full allowable f'_m used in flexure, shear, and axial stress will be used. If not checked, the allowable values will be reduced by one-half. The Uniform Building Code requires this reduction if Special Inspection is not provided.

Solid Grout

This applies to masonry only, and if this box is checked the weight of the wall will be based upon industry standard solid-grout weight for either lightweight, medium weight, or normal weight. If this box is not checked, the program will calculate the weight based upon grouting of only cells containing reinforcing. This also affects equivalent solid thickness for stem shear calculations

Short Term

This is used for masonry design only, and indicates the allowable overstress multiplier (1.33 for wind and seismic). For a concrete wall this does not apply since strength design is use, and this entry should be 1.0.

Stem Design

This allows you to design or check wall moment and shear at three locations: @ Top Support, @ Mmax Between Ends, and @ Stem Base. If base is pinned, the entries under @ Stem Base will be zero or dimmed.

Ht. Above Footing

This displays, from left to right, the distance up to lateral support, height to point of maximum positive moment, and at the base of the stem.

Rebar Depth "d"

From the wall thickness and center/edge condition specified, the program will determine the "d" to be used for design (using the internal tables and default modifications). See Rebar Position, above. For concrete, the program will automatically add to cover chosen one-inch allowance for one-half bar diameter, for determining "d" to be used.

Rebar Size

Select from the drop-down menu.

Rebar Location

Click the button for Center or Edge.

Rebar Spacing

Enter your trial choice, or for masonry, select from the drop-down menu.

Actual Moment

This will show moments at the indicated locations with (+) and (-) as applicable. For concrete the moments will be factored by 1.7.

Allowable Moment

This will be calculated based upon the data you have entered. For concrete, it will be based upon strength design (factored by 1.7).

Status

This indicates whether your stem design is OK at the selected height or at the base or displays $\mu > \phi M_n$ or $A_s < \min$ or $A_s > \max$.

Rebar Lap Req'd Above / Below

For masonry, the lap required is 48 bar diameters for $F_s = 24,000$ psi and 40 diameters for $F_s = 20,000$ psi.

For concrete, a Class B splice is assumed, which multiplies the development length by 1.3 (See ACI 12.15.2), and excludes reduction for stress level.

Note: The program does not compute or display bar cut-off points, which must be done manually, or extend positive reinforcing so it is acceptable.

Shear at Section

This is the total shear at the indicated height (factored for concrete).

Actual Shear

Unit shear stress at designated height computed by area = 12 "d".

Allowable Shear

Based upon $0.85 \sqrt{f'_c}$ for concrete and $\sqrt{f'_m}$ for masonry, reduced one-half for no inspection, and not to exceed 50 psi.

Footing Tab / Footing Dimensions

This is the screen where you design the footing, by manipulating the heel and toe widths so the actual soil pressure is less than allowable, or you can use the Automatic Footing Design button (described below) to size the footing. This screen also gives you choices for toe and heel reinforcing, or indicates if it is theoretically not required. It also suggests key reinforcing, if applicable.

Criteria	Loads	Stem	Footing	Stability	Description
Footing Dimensions		Key Dimensions & Sliding			
Footing Size					
Toe Width	<input type="text" value="3.750"/>	fc	<input type="text" value="3,000.0"/>	psi	
Heel Width	<input type="text" value="3.000"/>	Fy	<input type="text" value="60,000.0"/>	psi	
Total Width =	<input type="text" value="6.75"/>	Rebar Cover..			
Thickness	<input type="text" value="15.00"/>	In Hee	<input type="text" value="3.00"/>	in	
<input type="button" value="Center Stem on Footing"/>		In Toe	<input type="text" value="3.00"/>	in	
		Min As Ratio	<input type="text" value="0.0014"/>		
Rebar @ Stem Base : #7 @ 16.0					
Toe Reinf options:	<input type="text" value="#4@ 7.50 in, #5@ 11.75 in, #6@ 16.50 in, #7@ 22.50 in, #8@ 29.75"/>	Use #	<input type="text" value="0"/>		
		Max @	<input type="text" value="0.00"/>	in	
Heel Reinf options:	<input type="text" value="Not req'd, Mu < S * Fr"/>	Use #	<input type="text" value="0"/>		
		Max @	<input type="text" value="0.00"/>	in	
Key Reinf	<input type="text" value="#4@ 16.00 in, #5@ 24.75 in, #6@ 35."/>	Use #	<input type="text" value="0"/>		
		Max @	<input type="text" value="0.00"/>	in	
<input type="button" value="Footing Width Automatic Design"/>					

Toe Width

This is the width of the Toe of the footing, and is measured from the front edge of the footing to the front face of the stem. Can be set to 0.00 for a property line condition. All overturning and resisting moments are taken about the bottom-front edge of the toe.

Heel Width

Distance from front face of stem to back of heel projection. If a dimension is entered that is less than the stem width at the base, the program will automatically reset the heel dimension to at least the stem width. For a property line at the rear face of the stem, this dimension would be the stem width.

Total Footing Width

The calculated width of the footing, Toe Width + Heel Width.

Footing Thickness

Total footing thickness, NOT including the key depth (if used). For bending and shear design of the footing, the rebar depth "d" is taken as Footing Depth - Rebar Cover - 1/2" (to account for the rebar radius). If footing thickness is inadequate for shear capacity a red warning indicator will appear.

The footing thickness must be greater than the rebar embedment length required for the bottom stem reinforcing + rebar cover. If you enter a dimension less than required for stem bar embedment, a red message will appear at the top of the screen. The program adds the calculated hooked bar embedment from the STEM screen and adds it to the rebar cover you have chosen for the bottom of the footing (usually 3"). This will trigger the red warning. If inadequate thickness, increase the thickness, or change the stem dowels, until this message disappears.

Center Stem on Footing

Clicking this bar will adjust the toe and heel widths you have entered so stem is centered on the footing but overall width remains the same.

 f'_c

Enter concrete compressive stress for footing.

Fy

Allowable rebar yields stress to be used for design of footing bending reinforcement.

Rebar Cover in Heel/Toe

Distance from the face of concrete to edge of rebar. The program will add 1/2" to this value and subtract the result from the footing thickness to determine the bending "d" distance.

Minimum As Rebar Ratio

Enter the absolute minimum steel percentage to be used to calculate rebar spacing requirements (0.0018 Ag for Fy=60,000 psi). If the % steel required by stress analysis is less than 200/Fy, the minimum of (200/Fy -or- 1.333 * bending percentage required) is calculated and compared with the Minimum As% entered here, and the greater of the two used to calculate rebar spacing requirements.

Rebar at Stem Base

This is a reminder of the size and spacing of the bottom stem reinforcing, to make it easier for you to select toe reinforcing to match (toe reinforcing is usually the bottom stem dowel bars bent toward the toe).

Toe Reinforcing Options

This list gives you choices for reinforcing sizes and spacing for the bottom toe bars. Typically the toe bars are extensions of the stem dowels, which are bent out toward the toe. Therefore, you will probably want only to verify that the stem dowel bar size and spacing do not exceed the selections offered.

Heel Reinforcing Options

This list gives you choices for acceptable sizes and spacing of top heel bars. It is desirable to select a spacing that is modular with the stem dowel bars for ease of construction. Note: The program does not calculate the heel bar development length inward from the back face of the stem (where the moment is maximum). You can refer to Appendix B for development lengths in concrete, which can be adjusted for the stress level in the heel bars. When detailing footing reinforcing it is important to consider and specify development lengths for both toe and heel bars.

Rebar Selections

Use these three entries to pick your toe, heel, and if applicable, key reinforcing. The "Max @" message tells you the maximum spacing allowed for the bar selected.

[Footing Width Automatic Design]

Clicking this button will cause the program to iterate footing widths until the soil pressure, overturning stability, and sliding stability ratios are acceptable. You can select either a fixed toe or heel distance, or balance the toe and heel dimensions. You can also select whether the resultant must be within the middle third of the footing. After clicking "Design," the widths required will be displayed.

Automatic footing design is not available for Restrained Walls.

Footing Tab / Key Dimensions and Sliding

This screen tells you whether passive soil resistance plus friction resistance is adequate to resist sliding with at least a 1.5 safety factor. If inadequate, you can design a key. If a key is used, the previous footing screen will check whether reinforcing is required by first checking the plain concrete flexural capacity (for computing section modulus, 3" is deducted from the key width

per UBC '97). If the key depth to width ratio is less than about 2:1, it's usually adequate.

Criteria	Loads	Stem	Footing	Stability	Description
Footing Dimensions		Key Dimensions & Sliding			
Key Depth	<input type="text" value="24.000"/>	in	Key Width	<input type="text" value="12.000"/>	in
Key Location	<input type="text" value="2.000"/>	ft	from front of toe	<input type="checkbox"/> Align with Stem	
Soil over toe to neglect for sliding resistance	<input type="text" value="12.000"/>	in			
Footing/Soil Friction Factor	<input type="text" value="0.300"/>				
% PASSIVE Usable for Sliding Resistance	<input type="text" value="100.0"/>	%			
% FRICTION Usable for Sliding Resistance	<input type="text" value="100.0"/>	%			
Summary of Sliding Forces					
Lateral Force @ Base of Footing	2,961.1 lbs				
less Passive Pressure Force	- 3,202.0 lbs				
less Friction Force	- 2,058.8 lbs				
Added Resisting Force Required	0.0 lbs				
Added Resisting Force Required for 1.5 : 1 Factor of Safety	0.0 lbs				
Sliding Factor of Safety =			1.777 : 1.00		

Key Depth

Depth of the key below the bottom of footing. The bottom of the key is used as the lower horizontal plane for determining the size of the passive pressure block from the soil in front of the footing. Adjust this depth so the sliding safety factor is acceptable, but not less than 1.5. A depth greater than three feet or one-half the footing width is not recommended.

Key Width

Width of the key, measured along the same direction as the footing width. This is usually 12"-14", but generally not less than one-half the key depth so flexural stress in the key is adequate.

Key Location

Enter the distance from the front edge of the toe to the beginning of the key. Do not enter a distance greater than the footing width minus key width.

Align with Stem

Click this button to set front edge of key aligned with front of stem. If the key is then made the same width as the stem, the stem bars could extend down into the key to achieve development.

Soil Over Toe to Neglect for Sliding Resistance

Since the soil over the toe of the footing is usually loose and uncompacted, it may have little or no passive resistance. This entry gives you the option of neglecting any or all of the Height of Soil Over Toe that you had entered in the CRITERIA screen. You can neglect the soil over toe plus the footing thickness, if desired.

Footing/Soil Friction Factor

Enter this friction factor here, which is generally provided by the geotechnical engineer. It usually varies from 0.25 to 0.45.

% Passive Usable for Sliding Resistance

This may be a stated restriction in the geotechnical report. Enter a value from zero to 100%.

% Friction Usable for Sliding Resistance

This may be a stated restriction in the geotechnical report. Enter a value from zero to 100%.

Lateral Pressure @ Base of Footing

This is the total lateral force against the stem and footing which causes the wall to slide and which must be resisted. It is the total active pressure on the heel side less the active pressure on the toe side. The latter will be excluded if you choose to delete it on the OPTIONS screen.

Less Passive Pressure Force

This uses the allowable passive pressure in pcf and the available depth (soil above toe less height to neglect plus footing thickness) to compute the total passive resistance, again multiplied by the percent usable you selected. Weight due to toe surcharge, if applicable, will also be added. If a key is used, the available passive pressure depth will be to the bottom of the key.

Less Friction Force

This is the total vertical reaction multiplied by the friction factor, again multiplied by the percent usable you selected.

Added Resisting Force Required

If this is 0.0 lbs., the forces balance, but there may be no safety factor. Watch the Sliding Factor of Safety for an adequate value (usually 1.5). Add a key as required.

Added Resisting Force Required for 1.5:1 Safety Factor

This is the additional force required to be resisted by a key to achieve a 1.5 safety factor. If zero, no key is required.

Key Reinforcing

If flexural tension is insufficient to resist bending in key, a message will appear indicating reinforcing required. You can vary the width of the key until the message disappears. Or you can manually calculate reinforcing required.

Sliding Factor of Safety

This gives you the ratio of passive and friction resistance to the total lateral force. This should be at least 1.5.

NOTE : If lateral restraint is provided by an abutting floor slab (by checking the box on the CRITERIA > OPTIONS screen), the sliding factor of safety displays will be deleted, but the "Lateral Force @ Base of Footing" will be displayed for checking restraint adequacy of the slab.

Stability Tab

For Restrained Walls the STABILITY screen will appear differently, summarizing the conditions you have set regarding base fixity and base lateral restraint.

Criteria	Loads	Stem	Footing	Stability	Description
Footing Stability					
NOTE: Slab RESISTS sliding, stem is FIXED at footing					
Reaction Force at Top Restraint = 87.5 lbs					
Forces acting on footing for soil pressure					
>>> Sliding Forces are restrained by the adjacent slab					
Load & Moment Summary For Footing : For Soil Pressure Calc:					
Moment @ Top of Footing Applied from S	=				-291.7 ft-#
Surcharge Over Heel	=	lbs	ft		ft-#
Axial Load on Stem	=	lbs	ft		ft-#
Soil Over Toe	=	lbs	ft		ft-#
Surcharge Over Toe	=	lbs	ft		ft-#
Stem Weight	=	420.0 lbs	1.33 ft		560.0 ft-#
Soil Over Heel	=	183.3 lbs	1.83 ft		336.1 ft-#
Footing Weight	=	290.0 lbs	1.00 ft		290.0 ft-#
				Base Moment	= 894.4 ft-#
Total Vertical Force	=	893.3 lbs			
Moment used for Soil Pressure Calc = -1.1 ft-#					

A banner will display whether a slab is present to resist base sliding (box checked on CRITERIA > OPTIONS screen) and whether fixed or pinned at base, as previously selected on the STEM screen.

The reaction at the top restraint will be displayed.

The Sliding forces will be displayed, and indicate counteracting active pressure on toe side, if this option was selected on the Options screen.

The Moment at Top of footing applied from Stem is the theoretical overturning of the footing due to the reaction at the base of the stem, if the stem is "pinned" at the base. In actual practice the footing will be constructed integrally with the stem (not a true "pin") therefore this displayed overturning moment can be ignored provided the connection between footing and stem is sufficient. You can check the allowable moment at the base of the stem and compare it to the displayed "overturning" moment to verify this.

The "Moment used for soil pressure calc," if slab restraint is provided, is the total bearing load times the eccentricity (displayed on Results screen on right). If slab restraint is not provided, and since bottom of stem is considered "pinned," then this is (theoretically) the bottom-of-stem reaction multiplied by the footing depth and may generally be ignored per the preceding paragraph explanation.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results Tab

Results	Construction	Wall Loading
Soil Loading Results (Service load)		
Soil Pressure @ Toe		445.0 psf
Soil Pressure @ Heel		448.3 psf
Allowable		2,500.0 psf
Total Bearing Load		893.3 lbs
...resultant ecc.		0.01 in
Eccentricity within middle third		
Footing Results		
ACI Factored Pressure @ Toe		623.0 psf
ACI Factored Pressure @ Heel		627.7 psf
Mu:Design @ Toe		206.9 ft-#
Mu:Design @ Heel		54.4 ft-#
Heel moment OK using $M < S^*Fr$		
One-Way Footing Shears...		
Shear @ Toe		4.061 psi
Shear @ Heel		3.203 psi
Allow. Footing Shear		93.113 psi
Stability Ratios		
Overturning Restrained by Stem:Footing		
Sliding is Restrained by an adjacent slab		

Soil Pressure @ Toe and Heel

This is the resulting unfactored soil pressure for both the toe and heel. If the eccentricity is outside the middle third, the heel pressure will show 0.00. (Note: when the resultant is outside the middle-third, the program calculates the toe pressure assuming no "tension" at heel).

Allowable Soil Pressure

This is for your reference as input on the Criteria input Screen

Total Bearing Load

This is the sum of all vertical forces.

Resultant Eccentricity

Distance from center of footing to resultant soil pressure.

Eccentricity Within/Outside Middle Third

The resultant is outside the middle third of the footing width if the eccentricity is greater than one-sixth the footing width. (If outside the middle third, the program computes the toe soil pressure assuming no "tension" at heel.)

ACI Factored Soil Pressure @ Toe and Heel

ACI or AASHTO load factors are applied to all dead and live loads to determine total vertical load for soil pressure used in calculating footing moments and shears. This load is then applied at the same eccentricity calculated for service load soil pressures to yield the actual factored soil pressures for footing design using ultimate strength design principles. Note that since only factored vertical loads are applied at the non-factored resultant eccentricity, a true 1.7 load factor applied to lateral earth pressure is not used for footing design. If resultant vertical load eccentricity were to be calculated using factored loads, the distance would not truly represent a correct state of stress in the soil. ACI load factors are intended to give conservative results for stress. Calculation of a factored load eccentricity would give soil pressure diagrams that would not always represent the actual soil pressure distribution under the footing, and yield unreasonable results. Factored lateral earth pressure, however, is always used for concrete stem design.

Mu Design @ Toe/Heel

These are the factored (by 1.4) moments at face of stem for toe and heel moments. Since neither can be greater than the stem base moment (factored if concrete stem), the latter may govern. These moments will be reduced if you choose to neglect the upward soil pressure on the Criteria > Options tab.

A message will indicate which controls.

Shear @ Toe and Heel

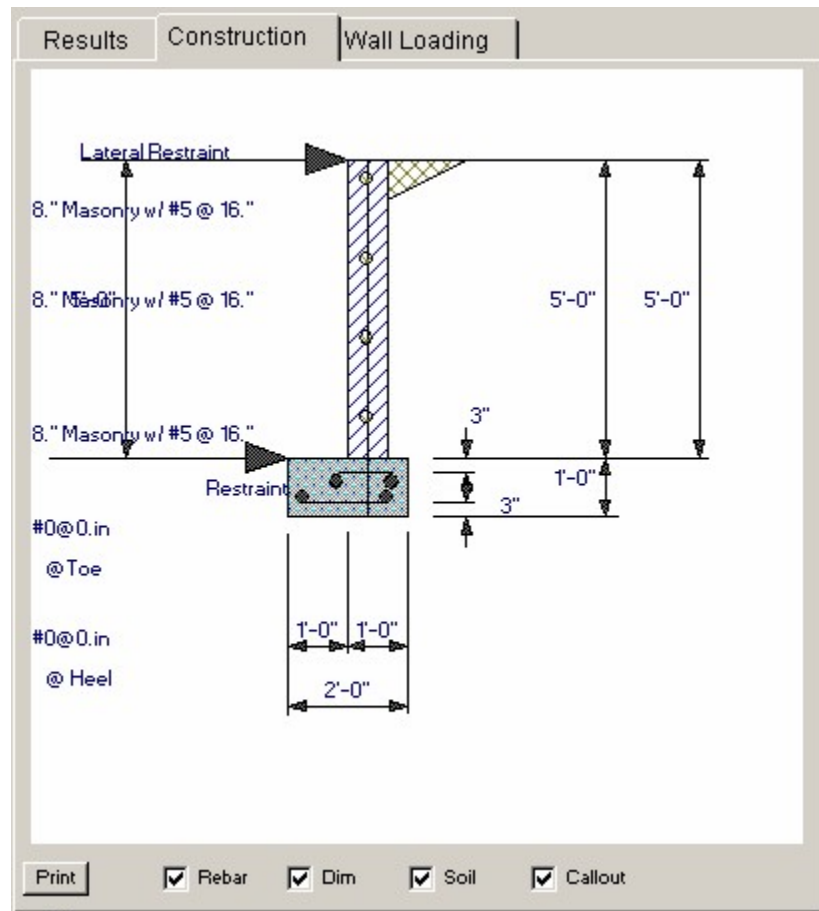
The actual shear is calculated from the one-way action in the footing at a distance "d" (footing thickness - rebar cover) from the toe side of the bottom stem section, and at the face of the stem on the heel side. If "d" is greater than the projecting toe or heel length, then the one-way shear is zero.

Allowable Footing Shear

The allowable unit shear equals $(0.85 * 2 * f'_c)^{1/2}$.

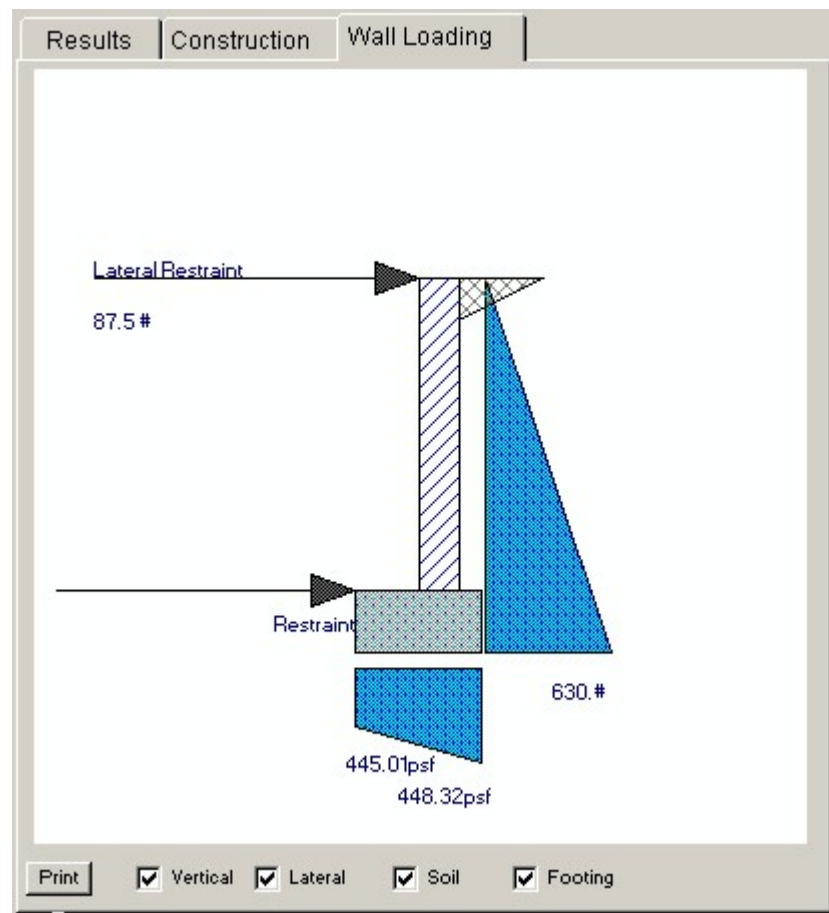
Construction Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Wall Loading Diagram Tab

This tab provides a sketch of the wall and its applied loads. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 7:20PM, 28 OCT 03
 Description: Collection of example problems

Scope: All programs in the Structural Engineering Library

Code Ref. ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Rev: 580000
 User: KW-0800001, Ver 5.8.0, 10-Sep-2003
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Restrained Retaining Wall Design

Page 1

c:\e2\Examples\ener\Retaining Wall

Description

Criteria		Soil Data		Footing Strengths & Dimensions	
Retained Height	= 5.00 ft	Allow Soil Bearing	= 2,500.0 psf	f_c =	3,000 psi
Wall height above soil	= 0.00 ft	Equivalent Fluid Pressure Method		Min. As %	= 0.0014
Total Wall Height	= 5.00 ft	Heel Active Pressure	= 35.0	Toe Width	= 1.00 ft
		Toe Active Pressure	= 0.0	Heel Width	= 1.00
		Passive Pressure	= 250.0	Total Footing Width	= 2.00
Top Support Height	= 5.00 ft			Footing Thickness	= 12.00 in
Slope Behind Wall	= 0.00 : 1	Footing Soil Friction	= 0.300	Key Width	= 0.00 in
Height of Soil over Toe	= 0.00 in	Soil height to ignore for passive pressure	= 0.00 in	Key Depth	= 0.00 in
Soil Density	= 110.00 pcf			Key Distance from Toe	= 0.00 ft
				Cover @ Top	= 3.00 in
Wind on Stem	= 0.0 psf			@ Btm	= 3.00 in

Design Summary

Total Bearing Load	= 893 lbs
...resultant ecc.	= 0.01 in
Soil Pressure @ Toe	= 445 psf OK
Soil Pressure @ Heel	= 448 psf OK
Allowable	= 2,500 psf
Soil Pressure Less Than Allowable	
ACI Factored @ Toe	= 623 psf
ACI Factored @ Heel	= 628 psf
Footing Shear @ Toe	= 4.1 psi OK
Footing Shear @ Heel	= 3.2 psi OK
Allowable	= 93.1 psi
Reaction at Top	= 87.5 lbs
Reaction at Bottom	= 542.5 lbs

Sliding Calcs Slab Resists All Sliding I
 Lateral Sliding Force = 542.5 lbs

Masonry Stem Construction

Thickness	= 8.00 in	f_m	= 1,500 psi	Short Term Factor	= 1.000
Wall Weight	= 84.0 pcf	F_s	= 24,000 psi	Equiv. Solid Thick.	= 7.600 in
Stem is FIXED to top of footing				n Ratio (Es/Em)	= 25.778
Block Type = Normal Weight				No Special Inspection	
Solid Grouted					

	@ Top Support	Mmax Between Top & Base	@ Base of Wall
	Stem OK	Stem OK	Stem OK
Design height	= 5.00 ft	2.77 ft	0.00 ft
Rebar Size	= # 5	# 5	# 5
Rebar Spacing	= 16.00 in	16.00 in	16.00 in
Rebar Placed at	= Center	Center	Center
Rebar Depth 'd'	= 3.81 in	3.81 in	3.81 in
Design Data			
$f_b/FB + f_a/F_a$	= 0.000	0.211	0.471
Moment....Actual	= 0.0 ft-#	130.4 ft-#	291.7 ft-#
Moment....Allowable	= 619.4 ft-#	619.4 ft-#	619.4 ft-#
Shear Force @ this height	= 0.0 lbs		350.0 lbs
Shear....Actual	= 0.00 psi		8.74 psi
Shear....Allowable	= 19.36 psi		19.36 psi
Rebar Lap Required	= 25.00 in	25.00 in	
Rebar embedment into footing	=		6.00 in

Other Acceptable Sizes & Spacings:

Toe: None Spec'd -or- Not req'd, $\mu_u < S * Fr$
 Heel: None Spec'd -or- Not req'd, $\mu_u < S * Fr$
 Key: No key defined -or- No key defined

Footing Design Results

	Toe	Heel
Factored Pressure	= 623	628 psf
μ_u : Upward	= 312	0 ft-#
μ_u : Downward	= 105	54 ft-#
μ_u : Design	= 207	54 ft-#
Actual 1-Way Shear	= 4.06	3.20 psi
Allow 1-Way Shear	= 93.11	93.11 psi

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Restrained Retaining Wall Design

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c:\ec56\examples.eas\Retaining Walls

Description

Summary of Forces on Footing : Slab RESISTS sliding, stem is FIXED at footing

Forces acting on footing for soil pressure >>> Sliding Forces are restrained by the adjacent slab

Load & Moment Summary For Footing : For Soil Pressure Calcs

Moment @ Top of Footing Applied from Stem	=		=	-291.7 ft-#
Surcharge Over Heel	=	lbs	ft	ft-#
Axial Dead Load on Stem	=	lbs	ft	ft-#
Soil Over Toe	=	lbs	ft	ft-#
Surcharge Over Toe	=	lbs	ft	ft-#
Stem Weight	=	420.0 lbs	1.33 ft	560.0 ft-#
Soil Over Heel	=	183.3 lbs	1.83 ft	336.1 ft-#
Footing Weight	=	290.0 lbs	1.00 ft	290.0 ft-#
Total Vertical Force	=	893.3 lbs	Base Moment =	894.4 ft-#

Soil Pressure Resulting Moment = -1. ft-#

4.3 Tapered Stem Wall

This program provides calculation procedures necessary to perform complete design and analysis of a conventional cantilevered retaining wall.

The retaining wall may be loaded with any of the following load combinations :

- Any angle of sloped backfill.
- Surcharge loading above heel or toe.
- Eccentric axial dead and live load on stem.
- Lateral and vertical load from an adjacent footing.
- Wind or seismic force on projecting portion of stem.
- An additional uniform lateral load may be applied to the wall.

The following overall dimensions can be specified:

- Retained height.

- Toe and heel dimension.
- Wall extension above retained height.
- Footing key depth, width, and location.
- Soil height over the toe.

The following stability checks are performed:

- Total overturning and resisting moment.
- Optional Inclusion of vertical active pressure on the rear face of the wall to resist overturning.
- Sliding resistance using both passive and active pressure.
- Both heel and toe of the footing are designed as follows:
- Toe Design - Find actual moment at stem face, check required minimum reinforcing, list rebar choices, and check one-way shear.
- Heel Design - Find moment at stem face, check required minimum reinforcing, list rebar choices and check one-way shear. User may neglect upward soil pressure for conservative design.

Also, the program has the unique ability to design screen walls (freestanding walls where the retained height is low and the projection above the soil is higher). Wind and seismic loads may be applied to the projecting portion, and an increased allowable stress may be used as allowed for short term loadings.

Basic Usage

- Entering Soil Data specifies the lateral earth pressures applied to the wall. Active Pressure will be used on over toe and/or heel unless Slope is non-zero. If this is the case, then the soil is sloped and Slope Pressure will be used behind the wall to generate lateral loads. Maximum Pressure can be entered to instruct the program to limit the lateral pressure intensity. (The pressure diagram then becomes uniform). Passive Pressure will be used for the full depth of soil in front of the wall to resist sliding. Soil Density will be used for soil weight, and Soil Height Over Toe will be used to define passive pressure height, vertical load, and will create an active pressure resisting overturning.
- You can apply two additional vertical Loads: an Axial Load to the top of the stem (with optional eccentricity), and Toe and Heel Surcharges. If the heel surcharge is permanent, you can specify that it Should Be Used To Resist Overturning.
- In addition to the lateral loads created by the soil above the footing, you can apply additional Lateral Loads to the wall. Enter a Lateral Loads Acting on the Stem Above Soil when your wall will extend above the soil, such as a screen or guard wall. Impact and bracing loads can be applied to the wall using the Additional Lateral Load item, letting you specify a load intensity and length. You can also enter an Adjacent Footing Load, by specifying the magnitude of load and position relative to the rear of the topmost stem section.
- The Wall and Footing Data section is used to specify the retained height, stem height above soil, and footing dimensions. Zero entries are permitted for the key and either toe or heel width. While using the program, you can easily change these values often and recalculate [F9] to determine soil pressures, overturning stability, and sliding stability.
- The critical footing wall design values are given in the Summary area, where you can review calculated results and then modify the wall and footing data as required.
- The program will perform a Sliding Check when you enter Footing/Soil Friction coefficients, and can Neglect a certain height of soil, if the soil in front of the wall is non-compacted.
- By simply entering the concrete strength, steel strength, and minimum steel percentage the program will provide a full Footing Analysis and Rebar List.
- Stem Design can be performed for up to five independent sections of the wall. By specifying Wall Construction Type, Design Height, and Wall Thickness and Reinforcing, each stem section can be easily refined for an optimum design.
- The Summary of Overturning and Resisting Moment table should be reviewed if you have any questions on how the vertical and lateral loads are being applied to the wall.
- When you are satisfied with the wall, Print or Save the current worksheet, choose Reset to start another wall design, or use the Access Menu to choose another program.

Unique Features

- Slope of backfill may be varied from flat to 45 degrees.

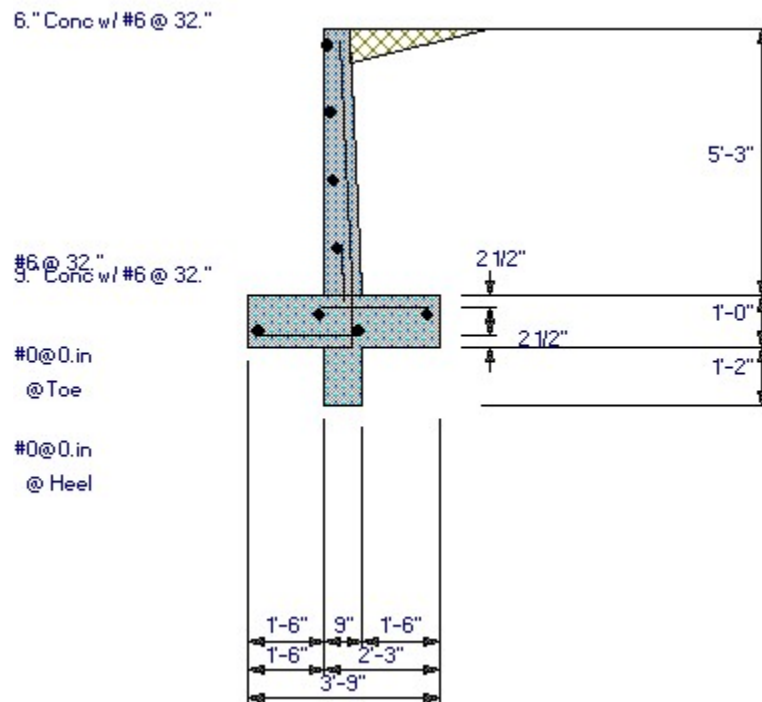
- Either a concrete or masonry stem can be specified. When concrete is chosen, the wall thickness, rebar size, and location is used to calculate the minimum spacing for the rebar. When masonry is specified, the option of special inspection is entered in addition to the above values, and the maximum rebar spacing is calculated at 8" modules.
- The program has the unique ability to design screen walls for conditions where the wall extends a distance above the soil which is much greater than the retained height.

Assumptions & Limitations

- Both active and passive pressures are applied as Equivalent Fluid Pressures.
- Friction coefficient is assumed to be applicable for both friction only and friction combined with passive pressure cases.
- Design for bending reinforcement in Toe and/or Heel of footing is calculated using d = thickness minus 3".
- If surcharge exists above the Toe or Heel, the soil height over those areas will be increased (internally) by the ratio of Surcharge/Soil Density.
- All concrete design is based on ACI Ultimate Strength Design.

Example

The data entry for this example is shown in the screen captures that accompany the Data Entry Tabs and Results & Graphics Tabs sections to follow.



Data Entry Tabs

This set of tabs provides entries for all input in this calculation. While you are entering data and switching between these tabs you can view the desired resulting information on the tabs on the right-hand side of the screen (calculated values, sketches, diagrams, etc.). A recalculation is performed after any entry data is changed. After each data entry you can view the results on the right-hand set of tabs.

General Data Tab

Criteria	Loads	Stem	Footing	Stability	Description
General Data Material Data Options					
General					
Retained Height	5.250 ft				
Wall height above retained soil	0.000 ft				
Height of Soil over Toe	0.000 in				
Water table height over heel	0.000 ft				
Soil Values					
Soil Slope	0.0 : 1				
Allow Soil Bearing	1,500.0 psf				
Lateral Pressure Method	E.F.P.				
Active Soil Pressure - Heel Side	45.00 psf/ft				
Active Soil Pressure - Toe Side	35.00 psf/ft				
Passive Pressure	250.00				
Soil Weight	110.00 pcf				

Retained Height

This is the height of retained earth measured from top of footing to the top of soil behind the stem (over the heel). When the backfill is sloped, the soil will slope away and upwards from this height. The actual retained height used for overturning and soil pressure calculations will be the retained height projected at the vertical plane of the back of the heel, but for stem moments, no such increase will be made. Using the spin-buttons you can vary this in 3-inch increments (you can type in any number). After each entry you can press the tab key to advance to the next entry, or use your mouse to position the cursor.

Wall Height Above Retained Soil

Use this entry to specify if the wall extends above the retained height. This entry is typically used to define a "screen wall" projection above the soil retained. This extension can be used as a weightless

"Fence" or a concrete or masonry stem section without any soil retained behind it. You can enter wind load on this projection using the entry "Load @ stem above soil" on the "Loads" tab. We'll handle the fence when we get to the STEM design screen.

Height of Soil Over Toe

Measured from the top of footing to top of soil, this may vary from a few inches to a few feet (it is measured in inches) depending upon site conditions. It is used to calculate passive soil pressure depth (considering "Ht. to Neglect" on "Sliding" tab). This soil can also be used to calculate an active pressure to reduce overturning; this is a choice on the Options Screen, and can have significant effect if the footing is well below grade.

Water Table Height Over Footing

If you want to design for a water table condition, enter the maximum height from top of footing to water table level. The program will then compute the added pressures for saturated soil on the heel side of the footing, including buoyancy effect, to calculate increased moments and shears on the stem, and overturning. Do not enter a height greater than the retained height, nor a liquid other than water.

Soil Slope

You may enter any backfill slope behind the wall. Use the drop-down menu or type the slope ratio as Horiz/Vert. The soil must be level or slope upward. Negative backfill slopes (grade sloping downward, away from the wall) are not allowed.

The program will use this slope to 1) include the weight of a triangular wedge of soil over the heel as vertical load, and 2) compute overturning based upon an assumed vertical plane at the back face of the footing extending from the bottom of the footing to ground surface - a steeper slope will result in a higher overturning moment. We suggest not using a slope steeper than 1.5 to 1.0 unless approved by the geotechnical engineer. The program will not accept a backfill slope steeper than the angle of internal friction.

Allowable Soil Bearing

The maximum allowable soil bearing pressure for static conditions. Using the spin buttons you can increment in 50 psf steps. Usual values for this vary from 1,000 psf to 4,000 psf or more.

Lateral Pressure Method

Here you can choose between E.F.P. or Rankine formula or Coulomb formula. EFP means "Equivalent Fluid Pressure," where you can enter a lateral soil pressure in psf per foot of depth. "Rankine" or "Coulomb" instructs Retain Pro to use the Rankine or Coulomb Method to calculate active and passive soil pressures using an entered angle of internal friction for the soil. When Rankine or Coulomb is chosen, the $K_a \cdot \text{Density}$ value for active pressure is computed.

Active Soil Pressure - Heel Side (EFP Method Chosen)

Active Pressure: $K_a \cdot \text{Gamma}$ (Rankine or Coulomb Method Chosen)

Enter the equivalent fluid pressure (EFP), or the angle of internal friction if Rankine or Coulomb is chosen, for the soil being retained that acts to overturn and slide the wall toward the toe side. This pressure acts on the stem for stem section calculations, and on the total footing+wall+slope height for overall stability and soil pressure calculations.

Commonly used values, assuming an angle of internal friction of 34, are 30 pcf for a level backfill; 35 pcf for a 4:1 slope; 38 pcf for a 3:1 slope; 43 pcf for a 2:1 slope; and 55 pcf for a 1.5:1 slope. These values are usually provided by the geotechnical engineer. If the Rankine or Coulomb method had been chosen, these values will be computed using those formulas.

When the retained soil is sloped, a vertical component of the lateral earth pressure over the heel can be applied vertically downward in the plane of the back of the footing. You can choose to apply this force for overturning resistance, sliding resistance, and/or for soil pressure calculations, by checking the boxes on the CRITERIA > Option screen.

Angle of Internal Friction (Rankine or Coulomb Method Chosen)

This value is entered in degrees and is the angle of internal friction of the soil. This value is usually provided by a geotechnical engineer from soils tests, but can also be found in reference books or building codes for various typical soil classifications. This value is used along with Soil Density within the standard Rankine and Coulomb equations to determine "Ka" and "Kp" multipliers of density to give active and passive soil pressure values.

Active Soil Pressure - Toe Side

If the EFP method is chosen, enter the active pressure to be used on the toe side of the wall. This active pressure is used along with the "Soil Height over Toe" value (entered on the Sliding tab) to calculate a stabilizing soil force on the wall. This front side of the wall is assumed to be level.

When either the Rankine or Coulomb method is chosen, the angle of internal friction is used in the Rankine formula with an assumed level toe-side slope.

The active pressure from soil over the toe partially counteracts the heel-side active pressure for overturning calculations.

Passive Pressure (EFP Method Chosen)**Passive Pressure: $K_p * \text{Gamma}$ (Rankine or Coulomb Method Chosen)**

This is the resistance of the soil in front of the wall to being pushed against to resist sliding. Its value is in psf per foot of depth (pcf). For the E.F.P. method, you input this value, which is usually obtained from the geotechnical engineer. If the Rankine or Coulomb method is chosen, it will be computed and entered for you. Its value usually varies from 100 pcf to about 350 pcf.

Soil Density

Enter the soil density for all earth above the toe and heel of the footing. This weight is used to calculate overturning resistance forces and soil pressures using the weight of the soil block over the projecting toe and heel of the footing. When surcharges are applied over the soil, the surcharges are transformed to equivalent uniform lateral loads acting on the wall by the ratio $\text{force} = (\text{Surcharge} / \text{Density}) * \text{Lateral Load}$. Input this value in lbs. per cubic foot. Usual values are 110 pcf to 120 pcf.

Material Data Tab

This screen allows you to change properties of masonry and concrete. It also allows you to decide what load factor (1.4 or 1.7) to use for factored soil pressure attributable to dead loads.

Criteria | Loads | Stem | Footing | Stability | Description

General Data | Material Data | Options

Masonry

Concrete block type **Normal Weight** ▾

Factor applied to f_m
for calculation of E_m **750.0**

Multiplier applied to
wall weight from tables **1.000**

Concrete

Concrete Weight **145.00** ▲/▼ pcf

ACI Factored Soil Pressure

Load Factor Used For Upward Factored Soil Pressure...
Calculate using 1.4*DL + 1.7*LL ▾

For Masonry

Concrete Block Type

This allows you to select Lightweight, Medium weight, or Normal weight concrete masonry units.

Factor Applied to f'_m for Calculation of E_m

The modulus of elasticity for masonry is $750 f'_m$ (UBC '97 2106.12.1). This entry allows you to select a multiplier other than 750.

Multiplier Applied to Wall Weight from Tables

This entry allows you to increase or decrease the internal default values of stem weights, as displayed on the STEM screen.

For Concrete

Stem concrete weight

This is usually 145-150 pcf, but may be changed with this entry.

Footing concrete weight

This option is necessary since if there is any buoyancy effect, this will reduce the effective weight of the footing concrete.

ACI Factored Soil Pressure

This gives you two choices for computing the factored moment in the toe. Select either a 1.7 load factor for both dead load and pressure attributable to live load and lateral soil pressure on the wall.

Alternatively, and less conservative, use a load factor of 1.4 for dead load (footing and superimposed earth) and 1.7 for live load and upward soil pressure attributable to lateral soil pressure.

Options Tab

This screen is critical to your design, since many subsequent calculation results will be affected. Review and check these boxes carefully.

The screenshot shows the 'Options' tab within a software interface. The main tabs are 'Criteria', 'Loads', 'Stem', 'Footing', 'Stability', and 'Description'. Underneath, there are sub-tabs for 'General Data', 'Material Data', and 'Options'. The 'Options' sub-tab is active and contains the following settings:

- Use AASHTO Load Factors ?
- Slab is present to resist all sliding forces
- Use these items when your surcharge may not be applied 100% of the time to resist the forces.
 - Use TOE Surcharge To Resist Sliding & Overturning ?
 - Use HEEL Surcharge To Resist Sliding & Overturning ?
- Use this item to ignore the upward soil pressure under the heel when calculating heel moments & shears.
 - Neglect Upward Pressure at Heel ?
- Toe Active Pressure Used... **To Resist Overturning** (dropdown menu)
- Use these choices to select when to use the vertical compo of active lateral soil pressure.
 - Use for Soil Pressure?
 - Use for Sliding Resistance ?
 - Use for Overturning Resistance ?

Slab is Present to Resist all Sliding Forces

Check this box when a slab is in front of the wall to resist lateral sliding. This negates sliding concerns (but check the slab if necessary). For restrained wall footings, it deletes the lateral force (base stem reaction) applied to the top of the footing, puts "not applicable" in the sliding ratio display, and dims the sliding entries on the FOOTING > KEY DIMENSIONS AND SLIDING sub-tab screen. The slab restraint is assumed to be at the top of the footing and the program does not allow it to be placed higher-if this condition occurs, append your printout with hand-calcs,

Use Toe Surcharge to Resist Sliding and Overturning

Checking this box will include the weight of soil overburden on the toe to resist overturning and add to its weight for frictional resistance.

Use Heel Surcharge to Resist Sliding and Overturning

Checking this box will include heel surcharge. If surcharge is live load and its use would be non-conservative, don't check this box.

Neglect Upward Pressure at Heel

For heel calculations you may choose to neglect the upward soil pressure, typically resulting in greater

heel moment. If this box is checked the Mu for upward loads will be zero.

Toe Active Pressure Used

Checking this box will apply the toe side active pressure to reduce overturning moment and reduce sliding force to a net sliding force to be resisted.

Choices for Use of Vertical Component of Active Pressure

The vertical component of the lateral pressure is applied at a vertical plane at the back of the footing. You can optionally use this to resist overturning, sliding, or for soil pressure calculations. (For the latter it can make a considerable difference). Checking these boxes applies the options. For a level backfill, this option will back-solve the EFP method to find the equivalent internal friction angle, then apply this vertical component equal to \tan . If either the Rankine or Coulomb method had been chosen, this

vertical component would be tangent of $\frac{\phi}{2}$.

Note that most texts suggest using the vertical component only to resist overturning. For a level backfill these options are usually not used.

Loads / Vertical Loads Tab

Additional loads on the wall are entered on these sub-tabs.

Criteria	Loads	Stem	Footing	Stability	Description
Vertical Loads					
Lateral Loads					
Surcharges					
Surcharge over Toe		0.00		psf	
Surcharge Over Heel		0.00		psf	
Axial Load Applied to Top of Stem					
Axial Dead Load		0.0		lbs	
Axial Live Load		0.0		lbs	
Axial Load Ecc.		0.00		in	
Adjacent Footing Data					
Adjacent Footing Load		0.00		lbs	
Footing Width		0.000		ft	
Eccentricity		0.00		in	
Wall to Ftg CL Dist.		0.00		ft	
Footing Type		Line Load			
Base Above/Below Soil at Back of Wall		0.00		ft	

Surcharge Over Toe

If other loads are imposed directly above the toe (such as a slab, storage, or moving load), these may be entered here (you have already entered the height of the soil over toe). This surcharge is divided by soil density and multiplied by active pressure to calculate an equivalent lateral load. This surcharge is

used to calculate soil pressure. You can use this surcharge to resist sliding and overturning by clicking the box on the CRITERIA > Options sub-tab.

Surcharge Over Heel

This surcharge is considered uniformly applied to the top surface of the retained soil (over the heel). It may be entered whether or not the ground surface is sloped, but is always taken as a vertical force. This surcharge is divided by the soil density and multiplied by the Active Pressure to create a uniform lateral load applied to the wall. You can use this surcharge to resist sliding and overturning by clicking the box on the CRITERIA > Options sub-tab.

Axial Loads Applied to Top of Stem

These loads are considered uniform load along the length of the wall. They are applied to the top of the topmost stem section and effect the design of masonry stems only. The dead and live loads are used to calculate stem design values and factored soil reaction pressures used for footing design. Only the dead load is used to resist overturning and sliding of the retaining wall.

Axial Load Eccentricity

This is the eccentricity of the axial load with respect to the centerline of the uppermost stem section. The eccentricity moves the load toward the toe, causing bending moments that are additive to those caused by the lateral soil pressure over the heel (negative eccentricities are not accepted).

Adjacent Footing Load

This entry gives you the option of placing a footing adjacent and parallel to the back face of the wall, and have its effect on the wall included in both the vertical and horizontal forces on the wall and footing. Refer to the General Reference Diagram for locations where input measurements should be taken.

For a "Line Load" the load entered is the total load per foot parallel to the wall (not lbs. per sq. ft).

If the adjacent footing is specified as "Square Footing" (not line load), the load entered should be the adjacent footing load divided by its dimension parallel to the wall, giving a pounds per lineal foot value, as for a continuous (line) footing.

A Boussinesq analysis is used to calculate the vertical and lateral pressures acting on the stem and footing. The program uses an assumed Poisson ratio of 0.3. (See Foundation Analysis and Design, 5th Edition, by J. E. Bowles, McGraw-Hill, pages 629-639)

Use of the Adjacent Footing may not be applicable if the horizontal distance from back face to stem to closest edge of adjacent footing is greater than the distance from top of wall footing to bottom of Adjacent Footing (i.e. outside an assumed line of influence).

When the Boussinesq analysis is used, the program may require additional computing time, depending upon the speed of your computer. To avoid this delay (which occurs any time any entry is changed) we suggest you use a vertical load of zero until your data entry is nearly finalized. Then enter the actual footing load and modify your final values.

Suggestion: For adjacent truck or highway loading, it may be preferable to use a heel surcharge (uniform) of 250 psf (or more) instead of treating it as an "adjacent footing."

Do not use this feature if the adjacent footing load is farther from the stem than the retained height, less the depth of the adjacent footing below the retained height, since at this distance it will not have significant effect on the wall.

Footing Width

Width of the adjacent footing measured perpendicular to the wall. This is necessary to create a one-foot long by Width wide area over which the load is applied.

Footing Eccentricity

This entry is provided in case the soil pressure under the adjacent footing is not uniform. Enter the

eccentricity of the resultant force under the adjacent footing from the centerline of the footing. Positive eccentricity is toward the toe, resulting in greater pressure at the side of the adjacent footing closest to the stem. The program will use the vertical load and eccentricity and create a trapezoidal pressure distribution under the adjacent footing for use with the Boussinesq analysis of vertical and lateral pressures.

Wall to Footing Centerline Distance

Distance from the center of the adjacent footing to the back face of the stem at the retained height.

Footing Type

This drop down menu selection allows you to enter either an isolated footing using the "Square Footing" selection, or a continuous footing using the "Line Load" selection.

Base Above/Below Soil at Back of Wall

Use this entry to locate the bottom of the footing with respect to the Retained Height. Entering a negative number places the footing below the soil. A positive entry would typically only be used when the soil is sloped and the footing resides "uphill". To insert a negative number, first type the number then press the "-" (minus) sign.

Note: If the "Adjacent Footing" is another retaining wall at a higher elevation, the Boussinesq analysis may be used for the vertical load applied to the soil from the wall, however the design must also consider the lateral (sliding) loads from that adjacent wall. This load could be applied as "Added Lateral Load", however this is at the discretion of the designer and is not within the scope of the program. Caution is urged for this condition. See discussion in the companion book: Basics of Retaining Wall Design.

Loads / Lateral Loads Tab

Load @ Stem Above Soil

This load (typically a wind load) will be applied to that part of the stem projecting above the retained height defined by the entry "Wall height above retained soil." It is used to calculate overturning moment and shear, stem design moment and shear, and soil pressures. Customary values are 10 psf or higher. Only a positive "+" value can be entered (i.e., the force may only be applied in a direction to add overturning, in the direction of the active soil pressure).

Added Lateral Load

This input allows you to specify an additional uniformly distributed lateral load applied to the stem. You can use it to apply a seismic load to the wall, an additional uniform lateral load due to soil pressure, or apply a short but intense load due to impact of a car or similar force (this case can be modeled by separating the "Height to Bottom" and "Height to Top" by just one foot, and using an "Added Lateral Load" equal to the total added force). This load is factored by 1.7 to calculate concrete moments and

shears.

Height to Top

This dimension defines the upper limit of the added lateral load measured from the top of the footing. Do not enter a dimension higher than the top of the wall ("retained height" plus "Wall height above retained soil").

Height to Bottom

This dimension defines the beginning (or bottom) of the added lateral load measured from the top of the footing.

Stem Tab

Criteria	Loads	Stem	Footing	Stability	Description
Material	Concrete		f_c	3,000.0	psi
			F_y	60,000.0	psi
Thickness : Top	6.000	in	Rebar Cover		
Base	9.000	in	2.00		
			in		
Stem Design...	<u>@ Height #2</u>	<u>@ Height #1</u>	<u>@ Stem Base</u>		
Ht. Above Footing	1.000	ft	0.500	ft	0.00 ft
Rebar Depth 'd'	5.93	in	6.21	in	6.50 in
Rebar Size	# 6		# 6		# 6
Rebar Spacing	32.000	in	32.000	in	32.000
Max. Req'd Spacing	18.00	in	18.00	in	18.00 in
Mu : Actual	978.8	ft-#	1,366.4	ft-#	1,845.0 ft-#
Mn*Phi: Allow.	4,281.5	ft-#	4,493.6	ft-#	4,705.8 ft-#
Status --->>	Stem OK		Stem OK		Stem OK
Rebar Lap Req'd	25.63	in	25.63	in	
Rebar Hook Develop Length into footing					6.00 in
Shear @ Section	690.9	lbs	863.0	lbs	1,054.3 lbs
Vu : Actual	9.71	psi	11.57	psi	13.52 psi
Vn*Phi : Allowable	93.11	psi	93.11	psi	93.11 psi

Wall Type

If tapered (battered) stem is selected, entry and data descriptions are described below. Taper can only apply to the inside face (the face against the soil).

Material

The default will be Concrete, since masonry cannot be tapered.

Thickness: Top and Base

Enter the thickness at the bottom of the stem and at the top.

f_c and F_y

Enter concrete strength and rebar yield stress.

Rebar Cover

Select the clearance you want. Against earth or exposed to weather and where formed, #5 and smaller bars are 1½" and 2" for #6 and larger (per ACI).

Stem Design

You can select two heights above the base to check moments and shears. These are identified as "@ Height #2" and "@ Height #1." The latter is the lower, and the default height at the base is 0.00 ft.

Ht. Above Footing

Select the two heights above the footing where rebar will be reduced for economy. Height #2 is highest and height at stem base will be fixed at 0.00. The #1 height should be at least the lap distance required above the stem top and base of the stem.

Rebar Depth "d"

This will be computed based upon the heights you have chosen and the amount of wall taper. One-half inch will be automatically added to rebar clearance to determine "d".

Rebar Size

Use the drop down menu to select #3 through #10 bar.

Rebar Spacing

Use the above data as a guide, but you will not be able to enter a spacing greater than 18 inches, which is the ACI permitted maximum.

Max. Allow. Spacing

This is the maximum permitted spacing, which per ACI is 18 inches.

Actual Moment (Mu)

These are factored (by 1.7) moments at the heights you have selected.

Compare this value with Allowable Moment, indicated below, to verify adequacy of your design at the selected height location.

Allowable Moment (Mn x)

This will be based upon the bar sizes and spacings you select.

Status

This indicates whether your stem design is OK at the selected height or at the base or displays $\mu > \phi M_n$ or $A_s < \min$ or $A_s > \max$.

Rebar Lap Splice Above / Below

This is the lap distance required above or below the Design Height. It is the development length multiplied by 1.3 (assuming a Class B splice) and without adjustment for stress level.

Rebar Embed Length into Footing

This is the same as for the Cantilevered (non-tapered) stem, and assumes the bar is hooked into the footing with a 90 bend and minimum 12 db bar extension.

Shear at Section

This is the total factored shear at the indicated height.

Actual Shear

Unfactored shear stress at designated height computed by $\text{area} = 12 \text{ "d"}$.

Allowable Shear

Based upon $0.85 \cdot 2 \cdot (f'_c)^{1/2}$ for concrete.

Footing Tab / Footing Dimensions

This is the screen where you design the footing, by manipulating the heel and toe widths so the actual soil pressure is less than allowable, or you can use the Automatic Footing Design button (described below) to size the footing. This screen also gives you choices for toe and heel reinforcing, or indicates if it is theoretically not required. It also suggests key reinforcing, if applicable.

Criteria | Loads | Stem | **Footing** | Stability | Description

Footing Dimensions | Key Dimensions & Sliding

Footing Size

Toe Width: ft

Heel Width: ft

Total Width = **3.75** ft

Thickness: in

f'_c : psi

F_y : psi

Rebar Cover..

In Heel: in

In Toe: in

Min As Ratio:

Rebar @ Stem Base : #6 @ 32.0

Toe Reinf options: Not req'd, $M_u < S * F_r$ Use # Max @ in

Heel Reinf options: Not req'd, $M_u < S * F_r$ Use # Max @ in

Key Reinf: #4@ 18.75 in, #5@ 28.75 in, #6@ 40. Use # Max @ in

Toe Width

This is the width of the Toe of the footing, and is measured from the front edge of the footing to the front face of the stem. Can be set to 0.00 for a property line condition. All overturning and resisting moments are taken about the bottom-front edge of the toe.

Heel Width

Distance from front face of stem to back of heel projection. If a dimension is entered that is less than the stem width at the base, the program will automatically reset the heel dimension to at least the stem width. For a property line at the rear face of the stem, this dimension would be the stem width.

Total Footing Width

The calculated width of the footing, Toe Width + Heel Width.

Footing Thickness

Total footing thickness, NOT including the key depth (if used). For bending and shear design of the footing, the rebar depth "d" is taken as Footing Depth - Rebar Cover - 1/2" (to account for the rebar radius). If footing thickness is inadequate for shear capacity a red warning indicator will appear.

The footing thickness must be greater than the rebar embedment length required for the bottom stem reinforcing + rebar cover. If you enter a dimension less than required for stem bar embedment, a red message will appear at the top of the screen. The program adds the calculated hooked bar embedment from the STEM screen and adds it to the rebar cover you have chosen for the bottom of the footing (usually 3"). This will trigger the red warning. If inadequate thickness, increase the thickness, or change the stem dowels, until this message disappears.

Center Stem on Footing

Clicking this bar will adjust the toe and heel widths you have entered so stem is centered on the footing but overall width remains the same.

f'_c

Enter concrete compressive stress for footing.

F_y

Allowable rebar yields stress to be used for design of footing bending reinforcement.

Rebar Cover in Heel/Toe

Distance from the face of concrete to edge of rebar. The program will add 1/2" to this value and subtract the result from the footing thickness to determine the bending "d" distance.

Minimum As Rebar Ratio

Enter the absolute minimum steel percentage to be used to calculate rebar spacing requirements (0.0018 A_g for $F_y=60,000$ psi). If the % steel required by stress analysis is less than $200/F_y$, the minimum of ($200/F_y$ -or- $1.333 * \text{bending percentage required}$) is calculated and compared with the Minimum As% entered here, and the greater of the two used to calculate rebar spacing requirements.

Rebar at Stem Base

This is a reminder of the size and spacing of the bottom stem reinforcing, to make it easier for you to select toe reinforcing to match (toe reinforcing is usually the bottom stem dowel bars bent toward the toe).

Toe Reinforcing Options

This list gives you choices for reinforcing sizes and spacing for the bottom toe bars. Typically the toe bars are extensions of the stem dowels, which are bent out toward the toe. Therefore, you will probably want only to verify that the stem dowel bar size and spacing do not exceed the selections offered.

Heel Reinforcing Options

This list gives you choices for acceptable sizes and spacing of top heel bars. It is desirable to select a spacing that is modular with the stem dowel bars for ease of construction. Note: The program does not calculate the heel bar development length inward from the back face of the stem (where the moment is maximum). You can refer to Appendix B for development lengths in concrete, which can be adjusted for the stress level in the heel bars. When detailing footing reinforcing it is important to consider and specify development lengths for both toe and heel bars.

Rebar Selections

Use these three entries to pick your toe, heel, and if applicable, key reinforcing. The "Max @" message tells you the maximum spacing allowed for the bar selected.

[Footing Width Automatic Design]

Clicking this button will cause the program to iterate footing widths until the soil pressure, overturning stability, and sliding stability ratios are acceptable. You can select either a fixed toe or heel distance, or balance the toe and heel dimensions. You can also select whether the resultant must be within the

middle third of the footing. After clicking "Design," the widths required will be displayed.

Automatic footing design is not available for Restrained Walls.

Footing Tab / Key Dimensions and Sliding

This screen tells you whether passive soil resistance plus friction resistance is adequate to resist sliding with at least a 1.5 safety factor. If inadequate, you can design a key. If a key is used, the previous footing screen will check whether reinforcing is required by first checking the plain concrete flexural capacity (for computing section modulus, 3" is deducted from the key width per UBC '97). If the key depth to width ratio is less than about 2:1, it's usually adequate.

Criteria	Loads	Stem	Footing	Stability	Description
Footing Dimensions		Key Dimensions & Sliding			
Key Depth	<input type="text" value="14.000"/>	in	Key Width	<input type="text" value="9.000"/>	in
Key Location	<input type="text" value="1.500"/>	ft from front of toe	<input type="button" value="Align w/Stem"/>		
Soil over toe to neglect for sliding resistance	<input type="text" value="0.000"/>	in			
Footing/Soil Friction Factor	<input type="text" value="0.400"/>				
% PASSIVE Usable for Sliding Resistance	<input type="text" value="100.0"/>	%			
% FRICTION Usable for Sliding Resistance	<input type="text" value="100.0"/>	%			
Summary of Sliding Forces					
Lateral Force @ Base of Footing	878.9 lbs				
less Passive Pressure Force	- 586.8 lbs				
less Friction Force	- 843.2 lbs				
Added Resisting Force Required	0.0 lbs				
Added Resisting Force Required for 1.5 : 1 Factor of Safety	0.0 lbs				
Sliding Factor of Safety =			1.627 : 1.00		

Key Depth

Depth of the key below the bottom of footing. The bottom of the key is used as the lower horizontal plane for determining the size of the passive pressure block from the soil in front of the footing. Adjust this depth so the sliding safety factor is acceptable, but not less than 1.5. A depth greater than three feet or one-half the footing width is not recommended.

Key Width

Width of the key, measured along the same direction as the footing width. This is usually 12"-14", but generally not less than one-half the key depth so flexural stress in the key is adequate.

Key Location

Enter the distance from the front edge of the toe to the beginning of the key. Do not enter a distance greater than the footing width minus key width.

Align with Stem

Click this button to set front edge of key aligned with front of stem. If the key is then made the same width as the stem, the stem bars could extend down into the key to achieve development.

Soil Over Toe to Neglect for Sliding Resistance

Since the soil over the toe of the footing is usually loose and uncompacted, it may have little or no passive resistance. This entry gives you the option of neglecting any or all of the Height of Soil Over Toe that you had entered in the CRITERIA screen. You can neglect the soil over toe plus the footing thickness, if desired.

Footing/Soil Friction Factor

Enter this friction factor here, which is generally provided by the geotechnical engineer. It usually varies from 0.25 to 0.45.

% Passive Usable for Sliding Resistance

This may be a stated restriction in the geotechnical report. Enter a value from zero to 100%.

% Friction Usable for Sliding Resistance

This may be a stated restriction in the geotechnical report. Enter a value from zero to 100%.

Lateral Pressure @ Base of Footing

This is the total lateral force against the stem and footing which causes the wall to slide and which must be resisted. It is the total active pressure on the heel side less the active pressure on the toe side. The latter will be excluded if you choose to delete it on the OPTIONS screen.

Less Passive Pressure Force

This uses the allowable passive pressure in pcF and the available depth (soil above toe less height to neglect plus footing thickness) to compute the total passive resistance, again multiplied by the percent usable you selected. Weight due to toe surcharge, if applicable, will also be added. If a key is used, the available passive pressure depth will be to the bottom of the key.

Less Friction Force

This is the total vertical reaction multiplied by the friction factor, again multiplied by the percent usable you selected.

Added Resisting Force Required

If this is 0.0 lbs., the forces balance, but there may be no safety factor. Watch the Sliding Factor of Safety for an adequate value (usually 1.5). Add a key as required.

Added Resisting Force Required for 1.5:1 Safety Factor

This is the additional force required to be resisted by a key to achieve a 1.5 safety factor. If zero, no key is required.

Key Reinforcing

If flexural tension is insufficient to resist bending in key, a message will appear indicating reinforcing required. You can vary the width of the key until the message disappears. Or you can manually calculate reinforcing required.

Sliding Factor of Safety

This gives you the ratio of passive and friction resistance to the total lateral force. This should be at least 1.5.

NOTE : If lateral restraint is provided by an abutting floor slab (by checking the box on the CRITERIA > OPTIONS screen), the sliding factor of safety displays will be deleted, but the "Lateral Force @ Base of Footing" will be displayed for checking restraint adequacy of the slab.

Stability - Resisting Moments

This screen presents in tabular form each component contributing to resisting moment, giving weights and lever arms from the front edge of the toe to the centroid of the weight.

Criteria	Loads	Stem	Footing	Stability	Description
Resisting	Overturning	Wall Tilt			
Resisting Moments					
	Force	Distance	Moment		
Soil Over Heel	866.3 lbs	3.00 ft	2,598.8ft-#		
Sloped Soil Over Heel	0.0				
Surcharge Over Heel	0.0				
Adjacent Footing Load	0.0				
Axial Dead Load on Stem	0.0				
Soil Over Toe	0.0				
Surcharge Over Toe	0.0				
Stem Weight(s)	475.8	1.82	864.3		
Earth above Sloping Stem	72.2	2.08	150.4		
Footing Weight	562.5	1.88	1,054.7		
Key Weight	131.2	1.88	246.1		
Vert. Component *	0.0				
Total Vertical	2,108.0 lbs				
Resisting Moment			4,914.2 ft-#		
Resisting/Overturning		2.692: 1.00			
* EFP method used. To calculate vertical component, angle of internal friction is back-solved using EFP and Rankine Equation. $\phi = 24.80$ degree					
These values are used for soil pressure calculations					
Force =	2,108.0 lbs	Moment =	4,914.2 ft-#		

Resisting/Overturning ratio is displayed.

For calculating the vertical component, if checked on the OPTIONS screen, and if the EFP method was chosen, the program will back-solve using the Rankine formula to obtain an equivalent internal friction angle.

The force and moment displayed at the bottom accounts for deduction of effect of vertical component, if box on CRITERIA > OPTIONS box has been checked.

Stability Tab / Overturning Moments

This screen presents in tabular form each component acting horizontally to overturn the wall/footing system. The centroid of each force is multiplied by its distance up from the bottom of the footing. The Heel Active Pressure includes the effect of surcharges and water table, if applicable, and its Distance is to the centroid of the total lateral force.

Criteria	Loads	Stem	Footing	Stability	Description
Resisting	Overturning	Wall Tilt			
Overturning Moments					
	Force	Distance	Moment		
Heel Active Pressure	878.9lbs	2.08ft	1,831.1 ft-#		
Toe Active Pressure	-17.5	0.33	-5.8		
Adjacent Footing	0.0				
Surcharge Over Toe	0.0				
Load @ Stem Above Soil	0.0				
Added Lateral Load	0.0				
Totals =	861.4 lbs				
	Overturning Moment		1,825.2 ft-#		
Resisting/Overturning		2.692: 1.00			

The total overturning moment is displayed, and the Resisting/Overturning ratio. The overturning moment is reduced by the toe side active pressure, if this option is selected on the Options screen.

Results & Graphics Tabs

This set of tabs provides the calculated values resulting from your input on the "Data Entry Tabs". Because a recalculation is performed with each data entry, the information on these tabs always reflects the accurate and current results, problem sketch, or stress/deflection diagram.

Results Tab

Results	Construction	Wall Loading
Soil Loading Results (Service load)		
Soil Pressure @ Toe		930.5 psf
Soil Pressure @ Heel		193.7 psf
Allowable		1,500.0 psf
Total Bearing Load		2,108.0 lbs
...resultant ecc.		4.92 in
Eccentricity within middle third		
Footing Results		
ACI Factored Pressure @ Toe		1,258.1 psf
ACI Factored Pressure @ Heel		261.9 psf
Mu:Design @ Toe		1,029.7 ft-#
Mu:Design @ Heel		701.7 ft-#
Heel moment OK using $M < S^*Fr$		
One-Way Footing Shears...		
Shear @ Toe		11,790 psi
Shear @ Heel		7,741 psi
Allow. Footing Shear		76,026 psi
Stability Ratios		
OTM Ratic		2.692 : 1.00
Sliding Rati	1.627	: 1.00

Soil Pressure @ Toe and Heel

This is the resulting unfactored soil pressure for both the toe and heel. If the eccentricity is outside the middle third, the heel pressure will show 0.00. (Note: when the resultant is outside the middle-third, the program calculates the toe pressure assuming no "tension" at heel).

Allowable Soil Pressure

This is for your reference as input on the Criteria input Screen

Total Bearing Load

This is the sum of all vertical forces.

Resultant Eccentricity

Distance from center of footing to resultant soil pressure.

Eccentricity Within/Outside Middle Third

The resultant is outside the middle third of the footing width if the eccentricity is greater than one-sixth the footing width. (If outside the middle third, the program computes the toe soil pressure assuming no "tension" at heel.)

ACI Factored Soil Pressure @ Toe and Heel

ACI or AASHTO load factors are applied to all dead and live loads to determine total vertical load for soil pressure used in calculating footing moments and shears. This load is then applied at the same eccentricity calculated for service load soil pressures to yield the actual factored soil pressures for footing design using ultimate strength design principles. Note that since only factored vertical loads are applied at the non-factored resultant eccentricity, a true 1.7 load factor applied to lateral earth pressure is not used for footing design. If resultant vertical load eccentricity were to be calculated

using factored loads, the distance would not truly represent a correct state of stress in the soil. ACI load factors are intended to give conservative results for stress. Calculation of a factored load eccentricity would give soil pressure diagrams that would not always represent the actual soil pressure distribution under the footing, and yield unreasonable results. Factored lateral earth pressure, however, is always used for concrete stem design.

Mu Design @ Toe/Heel

These are the factored (by 1.4) moments at face of stem for toe and heel moments. Since neither can be greater than the stem base moment (factored if concrete stem), the latter may govern. These moments will be reduced if you choose to neglect the upward soil pressure on the Criteria > Options tab.

A message will indicate which controls.

Shear @ Toe and Heel

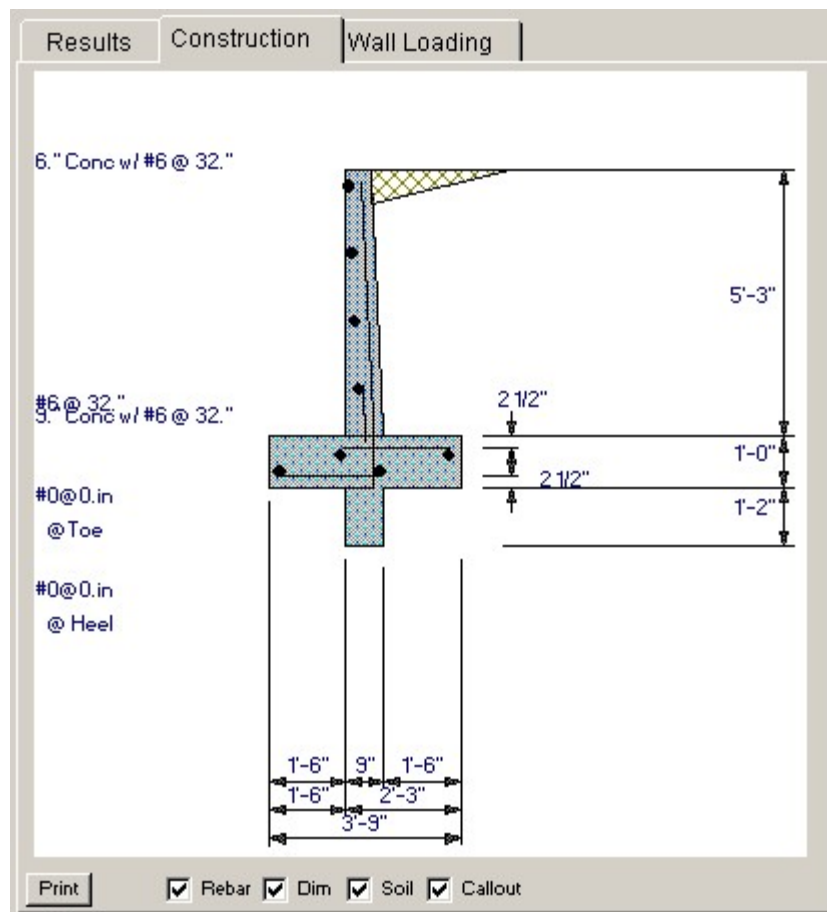
The actual shear is calculated from the one-way action in the footing at a distance "d" (footing thickness - rebar cover) from the toe side of the bottom stem section, and at the face of the stem on the heel side. If "d" is greater than the projecting toe or heel length, then the one-way shear is zero.

Allowable Footing Shear

The allowable unit shear equals $(0.85 * 2 * f'_c)^{1/2}$.

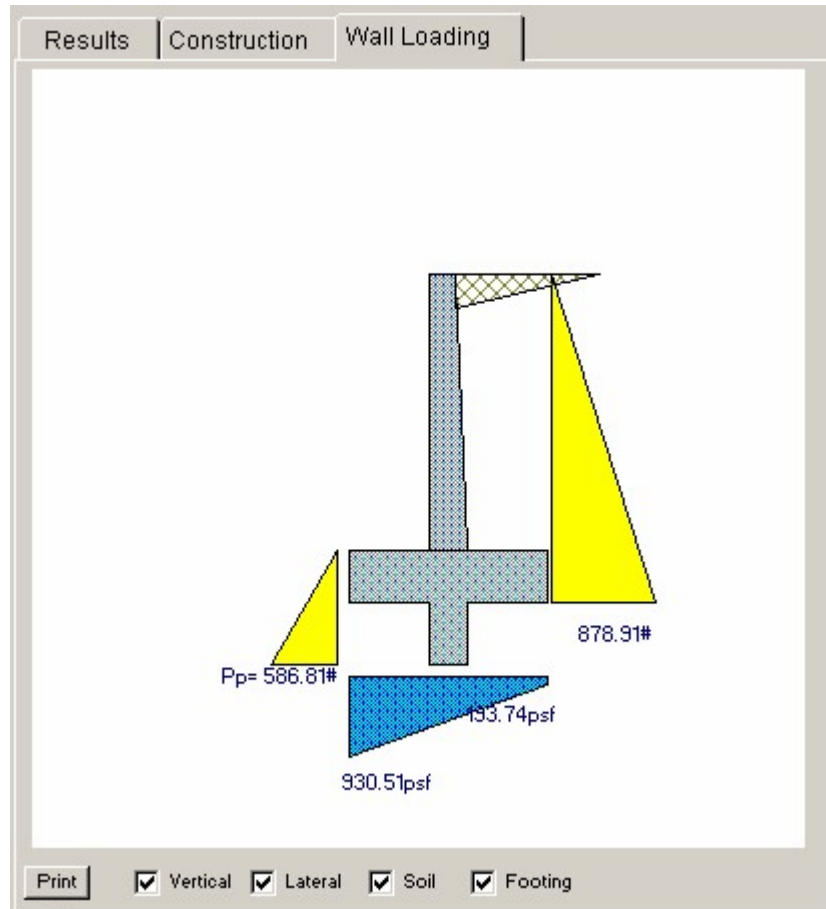
Construction Sketch Tab

This tab provides a sketch of the beam with loads and resulting values shown. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Wall Loading Diagram Tab

This tab provides a sketch of the wall and its applied loads. Using the [Print Sketch] button will print the sketch in large scale on a single sheet of paper.



Sample Printout

ENERCALC Engineering Software
 P.O. Box 188
 Corona del Mar, CA 92660
 Voice: 949-645-0151
 www.enercalc.com

Title: ENERCALC Example Problems Job # 97-000001
 Dsgnr: MDB Date: 7:24PM, 28 OCT 03
 Description: Collection of example problems
 Scope: All programs in the Structural Engineering Library
 Code Ref. ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Rev: 500000 Use 1:131-080001, W7.5.8.0, 10-29-03 ©1983-2003 ENERCALC Engineering Software
Tapered Stem Concrete Retaining Wall Design Page 1
 c:\e\example\code\retaining\wall

Description

Criteria	
Retained Height	= 5.25 ft
Wall height above soil	= 0.00 ft
Slope Behind Wall	= 0.00 : 1
Height of Soil over Toe	= 0.00 in
Soil Density	= 110.00 pcf
Wind on Stem	= 0.0 psf

Soil Data	
Allow Soil Bearing	= 1,500.0 psf
Equivalent Fluid Pressure Method	
Heel Active Pressure	= 45.0
Toe Active Pressure	= 35.0
Passive Pressure	= 250.0
Water height over heel	= 0.0 ft
Footing Soil Friction	= 0.400
Soil height to ignore for passive pressure	= 0.00 in

Footing Strengths & Dimensions			
fc =	2,000 psi	Fy =	40,000 psi
Min. As %	=	0.0018	
Toe Width	=	1.50 ft	
Heel Width	=	2.25	
Total Footing Width	=	3.75 ft	
Footing Thickness	=	12.00 in	
Key Width	=	9.00 in	
Key Depth	=	14.00 in	
Key Distance from Toe	=	1.50 ft	
Cover @ Top	=	2.50 in	@ Btm = 2.50 in

Design Summary	
Total Bearing Load	= 2,108 lbs
...resultant ecc.	= 4.92 in
Soil Pressure @ Toe	= 931 psf OK
Soil Pressure @ Heel	= 194 psf OK
Allowable	= 1,500 psf
Soil Pressure Less Than Allowable	
ACI Factored @ Toe	= 1,258 psf
ACI Factored @ Heel	= 262 psf
Footing Shear @ Toe	= 11.8 psi OK
Footing Shear @ Heel	= 7.7 psi OK
Allowable	= 76.0 psi
Sliding Stability Ratio	= 1.63 OK
Sliding Calc (Vertical Component NOT Used)	
Lateral Sliding Force	= 861.4 lbs
less 100% Passive Force	= 586.8 lbs
less 100% Friction Force	= 843.2 lbs
Added Force Req'd	= 0.0 lbs OK
...for 1.5 : 1 Stability	= 0.0 lbs OK

Tapered Concrete Stem Design Data			
Thickness at TOP	= 6.00 in	Fy =	60,000 psi
Thickness at BOTTOM	= 9.00 in	fc =	3,000 psi
Rebar Cover (rebar center to concrete face)	2.00 in		
	@ Height #1	@ Height #2	@ Base of Wall
Design height	Stem OK = 1.00 ft	Stem OK = 0.50 ft	Stem OK = 0.00 ft
Rebar Size	# 6	# 6	# 6
Rebar Spacing	32.00 in	32.00 in	32.00 in
Rebar Depth 'd'	5.93 in	6.21 in	6.50 in
Design Data			
Mu...Actual	= 978.8 ft-#	1,366.4 ft-#	1,845.0 ft-#
Mn * Phi...Allowable	= 4,281.5 ft-#	4,493.6 ft-#	4,705.8 ft-#
Shear Force @ this height	= 690.9 lbs	863.0 lbs	1,054.3 lbs
Vu...Actual	= 9.71 psi	11.57 psi	13.52 psi
Vn * Phi...Allowable	= 93.11 psi	93.11 psi	93.11 psi
Rebar Lap Required	= 25.63 in	25.63 in	
Rebar embedment into footing	=		6.00 in

Footing Design Results		
	<u>Toe</u>	<u>Heel</u>
Factored Pressure	= 1,258	262 psf
Mu' : Upward	= 1,266	444 ft-#
Mu' : Downward	= 236	1,146 ft-#
Mu: Design	= 1,030	702 ft-#
Actual 1-Way Shear	= 11.79	7.74 psi
Allow 1-Way Shear	= 76.03	76.03 psi

Toe Reinforcing	= None Spec'd
Heel Reinforcing	= None Spec'd
Key Reinforcing	= None Spec'd
Other Acceptable Sizes & Spacings	
Toe: Not req'd, Mu < S * Fr	
Heel: Not req'd, Mu < S * Fr	
Key: #4@ 18.75 in, #5@ 28.75 in, #6@ 40.	

Summary of Overturning & Resisting Forces & Moments

Item	...OVERTURNING...				...RESISTING...		
	Force lbs	Distance ft	Moment ft-#		Force lbs	Distance ft	Moment ft-#
Heel Active Pressure	= 878.9	2.08	1,831.1	Soil Over Heel	= 866.3	3.00	2,598.8
Toe Active Pressure	= -17.5	0.33	-5.8	Sloped Soil Over Heel	=		
Surcharge Over Toe	=			Surcharge Over Heel	=		
Adjacent Footing Load	=			Adjacent Footing Load	=		
Added Lateral Load	=			Axial Dead Load on Stem	=	0.00	
Load @ Stem Above Soil	=			Soil Over Toe	=		
Seismic Load	=			Surcharge Over Toe	=		
Total	= 861.4	O.T.M. =	1,825.2	Stem Weight	= 475.8	1.82	864.3
Resisting/Overturning Ratio	=	2.69		Earth above Sloping Stem	= 72.2	2.08	150.4
Vertical Loads used for Soil Pressure	=	2,108.0 lbs		Footing Weight	= 562.5	1.88	1,054.7
Vertical component of active pressure NOT used for soil pressure				Key Weight	= 131.2	1.88	246.1
				Vert. Component	=		
				Total =	2,108.0 lbs	R.M. =	4,914.2