Engineering with the Spreadsheet

Structural Engineering Templates Using Excel

Craig T. Christy

ASCE PRESS

Engineering with the Spreadsheet

Microsoft Excel software is not included.
Excel 2000 or above is recommended.

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Usually, authors include a page to thank people for contributions
to getting a project done.

I'd like to thank the United States Selective Service System for providing the motivation that made me stay in school in hopes of avoiding the draft and thus complete an engineering degree in four years.

I passed the Engineers in Training exam in the spring.
I received my draft notice the following November.

I served for two and a half years.

Oh, well.

Craig T. Christy, P.E.
October 10, 2005

Registered Structural Engineer in:	Oregon Washington Hawaii
Registered Civil Engineer in:	Alaska California

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ENGINEERING with the SPREADSHEET

A	B	C	D

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Contents

An asterisk (*) indicates chapters in the book but not on the CD-ROM.

A B C D E F G H I J K L

INTRODUCTION

The text of this manual has been assembled in Microsoft's Excel spreadsheet program.

This manual and CD-ROM are intended for use by professional engineers and college students alike. Examples include fundamental concepts and complex designs.

The spreadsheet is becoming an essential engineering tool. It allows the user to create consistent calculations and presentations and reduce the time spent on both routine and complex calculations. This manual puts you in touch with many of the tools you need to do your work.

You, as an engineer, must understand the calculations you produce. Computer program answers and choices from tables are good if documentation is provided. "Black box" and table answers without documentation don't demonstrate professional understanding. What's more, codes can be interpreted in different ways by other engineers and building officials. This requires the ability to adjust the program or spreadsheet templates to meet these varied requirements. Also, no program or template will answer all of the possible combinations of inputs and required outputs.

Stated another way, due diligence is required. There is no such thing as "engineering-in-a-can" -- blind faith in computer solutions does not serve as due diligence.

The templates on the CD-ROM are completely open to your view and can be modified to suit your needs. Put your own logo in place of the "Consulting Company" logo, but please leave the ***Engineering with the Spreadsheet*** title and the **Copyright 2006 American Society of Civil Engineers** somewhere in the header.

The templates are yours to use and may be issued to the Building Department and other authorities, customers, and interested parties but may not be repackaged and resold. If you use a template as part of another, new application that you intend to sell, be sure to leave an appropriate attribution next to the parts of the template you have adapted and contact ASCE to make any other arrangements to assure that you stay within the law.

This book was started twenty years ago as a means of keeping notes for using Lotus 1-2-3.

These notes evolved into a manual for short seminars and then as a 400 level class at Portland State University entitled "Engineering with the Spreadsheet." Over the years, more and more material was created for a host of engineering projects. Some of that material has been edited for this manual and the included CD-ROM.

A B C D E F G H I J K L

INTRODUCTION -- Continued

We start out with how to use the spreadsheet as engineers. That's a few of the basics. The last chapter in this section is "Takedown." This is used at the beginning of class to make sure that everyone is on the same page. Many inexperienced users who come to class will get out a calculator to do work that should be done by the spreadsheet.

Advanced applications start with the "Regression Analysis" chapter. This chapter was created to help me with beginning statistics and back up some testing that I was doing on shear walls for a customer. This is the stuff that we were supposed to learn in college -- but didn't.

The "Pole" chapter begins the process of addressing the issues of presentation as do all of the design templates. It is important to present calculations that can be reviewed by someone else. This entails an audit trail that is visible on the printed calculation and documentation. Pictures and diagrams are a big help. Range name your variables for reviewing the template itself . You can use the spreadsheet's drawing tools to highlight information, draw arrows from a cell to dependent cells, create diagrams, and so on.

There are complete calculation sets in the manual which start with the cover page and table of contents followed by calculations for seismic, wind loads and the actual design from the top of the structure to the anchor bolts and soils. I feel that this is rarely done in engineering textbooks because any calculation set will contain errors and debatable philosophical issues. If you ask five engineers to design something a little out of the ordinary, you'll get seven answers. Engineering is as much an art as it is a science.

Finally, the manual contains a comprehensive collection of concrete design templates. The manual is setup so that examples are complete and you can follow the entire design process.

The templates use Imperial input and output units. The American Concrete Institute (ACI) and the International Building Code (IBC) use Imperial units. The IBC follows Imperial units with SI (System Internationale) units, the ACI does not. Word on the street has it that even Europe is having difficulty with SI units. The old meters-kilograms-seconds (mks) system is much easier to handle and less error prone. If the elites had let well enough alone, we might be using the mks system by now. The "Units" chapter contains conversions for Imperial to mks and SI and, conversely, SI to Imperial and mks. Unit conversions are presented as active formulas rather than tables which can be more easily misinterpreted.

Many of the templates contain formulas with numbers and units and with formulas comprised of units only. This is unit analysis which is vital to understanding the design and getting the right answer.

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INTRODUCTION

Not included on the CD-ROM

1

ENGINEERING with the SPREADSHEET

A B C D E F G H I J K L

SOME HISTORY

In the beginning, in the land of WA there was Bill Gates and Michael Allen and a host of few. They struck a deal with the giant IBM and a "hacker" who had an operating system that operated with the Intel chip sets of the day. They bought the operating system and named it QDOS (quick and dirty operating system).

IBM's first attempt at a personal computer didn't work out. Management turned the project over to a "skunk works" that came up with the first usable IBM PC. The leader died in an airline crash coming into Dallas, Texas. I met and shook the left hand of one of the survivors (also with IBM) of that mishap -- his badly burned right hand held a beer.

Mich Kapor sat down next to Dan Bricklin on another airliner. Dan Bricklin had created VisiCalc for the APPLE Computer, Altos, and others. It was on Dan Bricklin's electronic spreadsheet that I first learned the power of this medium. I still have books and programs bearing his name in my library.

Mitch Kapor started the LOTUS company in the land of MA. Lotus started out with a staff of about 50. Lotus created a spreadsheet that worked with QDOS on the IBM PC.

fool proof nothing is so foolproof that some talented fool can't make a mess of it

anything that can go wrong will go wrong -- so design accordingly

hacker in the "old days" (1980) a hacker was someone who banged out code for whatever purpose. I was considered a hacker because I used the spreadsheet and other applications to do engineering. Now the term "hacker" has a bad connotation.

WA Washington State

MA Massachusetts State

OR Oregon State

QDOS and Lotus helped IBM launch the personal computer revolution in the early '80's. Lotus brought out the LOTUS 1-2-3 spreadsheet. This was good -- especially the release 2 version. MICROSOFT kept growing through various means. Eventually, Microsoft brought out EXCEL in direct competition with LOTUS. We now have EXCEL. row 120

This manual was originally based upon Lotus 1-2-3. It was meant to be generic. This revised manual will, hopefully, be generic also. Its principles should transcend all sorts of software.

This manual (and disk) are aimed at presentation as much as analytical capability. Your spreadsheet template can be complete and accurate but, If it looks ugly, people will not read it. However, if both the template and the printed document use diagrams, pictures, and an audit trail, people will take your spreadsheet presentation seriously and use it. That's the whole point. row 130

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NOTES

ENGINEERING with the SPREADSHEET

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PART 1:

A FEW OF THE BASICS

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ENGINEERING with the SPREADSHEET

_2 Tips.xls

A B C D E F G H I J K L M N

USING THIS BOOK AND CD

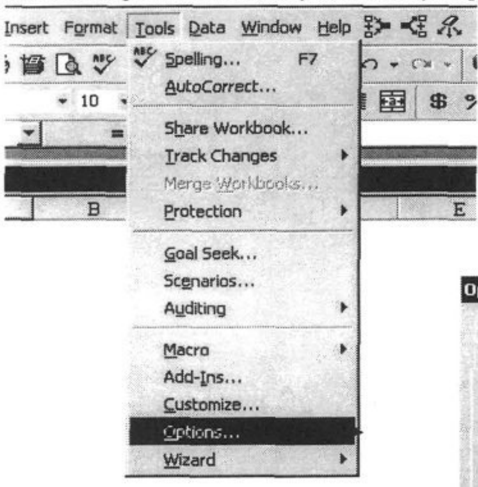
If you have a question or comment, e-mail to: **ice-or.com** website: **http://www.ice-or.com**
Send your spreadsheet if that will help. This is much faster and easier to understand than a phone conversation. We can always talk later.

Make an **ARCHIVE COPY** of your disk before using it **OR**, copy your disk onto your hard drive and then archive the original disk.

A spreadsheet template is not meant to be tight code. The spreadsheet gives us the opportunity to provide a clear audit trail and uncomplicated code. row 20

Keep file naming consistent. Develop your own standard format based upon date performed, job #, and etcetera, so that files will be easy to find in the future. For example, *saving a job on September 15, 1997 might be given the name: MY091597file or MY 091597 file.*

Explore the graphing features in the demonstration files. Graphics are an excellent troubleshooting tool. Excel allows you to locate your graph adjacent to your calculations.



row 30

Figure 2-1 The Tools drop down menu.

Templates may be set to a recalculation mode through the Excel Tools menu. When using manual recalculation, press the **[F9]** key to recalculate.

You may also set the calculation mode to Iteration. This is important for some templates.

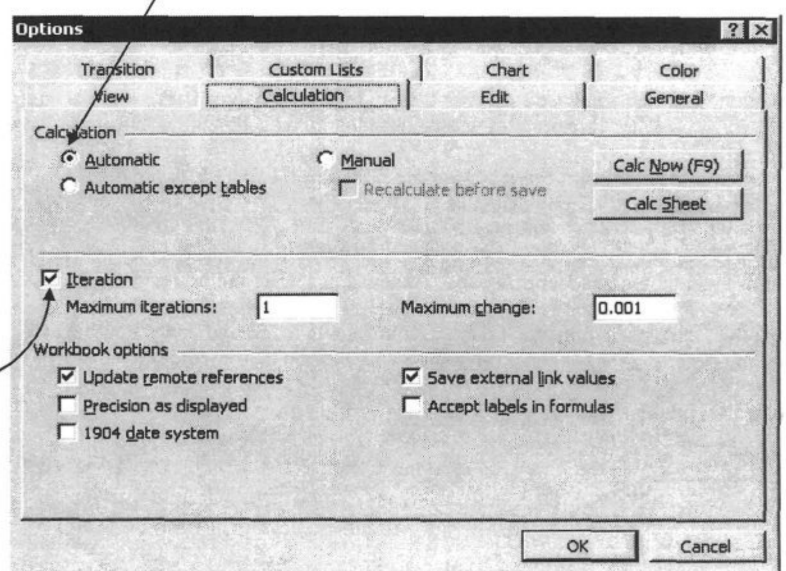


Figure 2-2 The Options menu.

When doing an example, make sure that the input values in your template completely match the values in the figures, otherwise your answer may differ from the manual's.

Use the spreadsheet as a calculator. With practice, this becomes faster and more reliable than using the hand-held calculator.

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USING THIS BOOK AND CD -- Continued

Using a **ZIP** file makes life a bit easier in that, when you need several files from a **CD-ROM**, you can copy and **unzip** a directory to **hard disk** without having to set each file from **Read Only** to **Archive** status in the file **Properties** menu.

HIJAAK PRO by QUARTERDECK was used to "screen capture" images like the one above.
Other images were created with **AutoCAD** and then copy-clipped into the spreadsheet.
Still, other images and diagrams were made with native **Excel** drawing tools.
Some screen captures were made with the **[Print Screen]** key located on your keyboard.

A collection of print density arrangements are used in this manual. All sheets use a 9 or 10 line header which repeats with each printed page.

Each page is approximately 50, 60, 70, or 80 lines deep. The 80 line format most closely represents the old 132 characters per line format with lines and columns spaced at multiples of 1/8 inch. This gets a little small to read and fax but it is the easiest module to create.

All sheets are labeled at 10 row intervals. This helps in organizing work and with phone conversations. People rapidly adapt to using row numbers instead of page numbers or, where row numbers are duplicated because of using other templates, then use a page number or file name with a row number.

The black bar at the top of the sheet names the module below and sometimes contains other information. Row numbers may be included in this bar or just above it. Black bars within the page usually terminate at column **G** or **H**.

Also, in the repeated header, the columns are labeled. Almost all of ICE's templates use columns **A** through **N**. It just seems to work better that way.

The repeating header should also contain the time, date, and filename. These are real time savers when you need to find a file to reuse or determine which is the most recent and (probably) valid calculation.

Include some type of graphic symbol in the header to identify the module or project. Engineers, in particular, really appreciate this.

Write **VOID** in red pencil on discarded calculations and throw them into a box for safe keeping. Use a red pencil because it can be erased if necessary. You must use white-out or a large white label with red ink.

The spreadsheet template is meant to be easy for anyone to follow and verify. For that reason, information is arranged in columns. The column arrangement may include logic matrices.

The standard template layout is:

right justified

label	variable	unit	explanation		notes and documentation
					reference the books you use by chapter and page number
m	**3**	unitless	slope		
X	**1**	in	measurement along the X-axis		
b	**6**	in	Y intercept at X = 0		reference codes by code number and date
Y	**9**	in	m * X + b	the equation	explain the meaning of labels
			3 * 1 in + 6 in	the concatenated equation (put your cursor on this cell to see how the equation was created)	**m** slope of a straight line
highlight the answer					
Y	**9**	in			

another type of highlight

Figure 2-3 Our standard template layout for ease of use.

USING THIS BOOK AND CD -- *Continued*

Or highlight and make notes by hand -- which is probably the best way to draw someone's eye to your conclusion.

Also, a few hand written comments and parallel calculations in the notes column **G** through **N** will demonstrate to others that you actually did the work.

Cautions

Don't move an input value into another input cell. Instead, copy the input to another location with the spreadsheet *Copy Paste commands --* ***[Ctrl] [c]*** *and* ***[Ctrl] [v]*** *are the keyboard shortcut commands.*

Putting labels instead of values or formulas into numerical cells returns a 0 (zero) value. Dividing by a label will yield a **#NAME?** flag in the template. Dividing by 0 yields a **#DIV/0!** flag.

Move an entire template to another template with the Cut and Paste commands. This preserves your absolute references.

Check your input and results with graphing.

Do the math in your head.

Anyone of questionable ability can alter the template. It is not compiled programming code. Results can be tampered with.

Try to keep all columns the same width. Format the entire sheet as 10 point Arial font vertically centered in the cell(s).

Avoid complicated sheet formatting -- complication will always come back to bite you.

Use a space between math operators and the variables or numbers in your presentation. For example:

(5 * 2 + 3) * m /b

When displaying an equation as active numbers in a text/formula string, the ^ symbol and *traditional spreadsheet math characters must be used because nothing can be formatted in* a formula string. However, the *Symbols Chapter* does have characters that are useful in *formula strings. Look through the templates for examples.*

Using Textbook Examples

Textbooks and references are often compiled by typists who don't understand the material and arranged and typeset by people who can't possibly be expected to know much about what they are working with or their audience. For this reason, figures and diagrams are located away from the text and the text has subtle errors. Examples are often broken up over several pages and mixed in with other examples. Examples are provided without values and units that help to explain the meaning of those values.

The copy machine has been readily available to most of us for the last 30 years. To create a preliminary template layout, copy the parts of the text or reference book you need and then cut and paste the examples into an orderly, modular format. Regular cellophane tape and copy paper works well. Don't use old printouts because you may not know which side, at a glance, has your information.

Code books usually present the principle formulas first followed by the supporting values and formulas. Spreadsheet modules are typically laid out so that each successive formula builds on the previous formulas. In this way, each formula references inputs and formulas above it and not below -- this works well for an audit trail and troubleshooting.

A B C D E F G H I J K L M N

ADJUSTING EXCEL FOR EASE OF USE

There are a lot of things about *Lotus 1-2-3* that were easier to use than Excel fresh out of the box.

For math intensive work, you can set some of the Excel operating parameters to work like *1-2-3*. This manual is based upon using the Transition formula evaluation and Transition formula entry features.

In the Excel Tools menu, be sure to enable:

Transition navigation keys
Transition formula evaluation
Transition formula entry

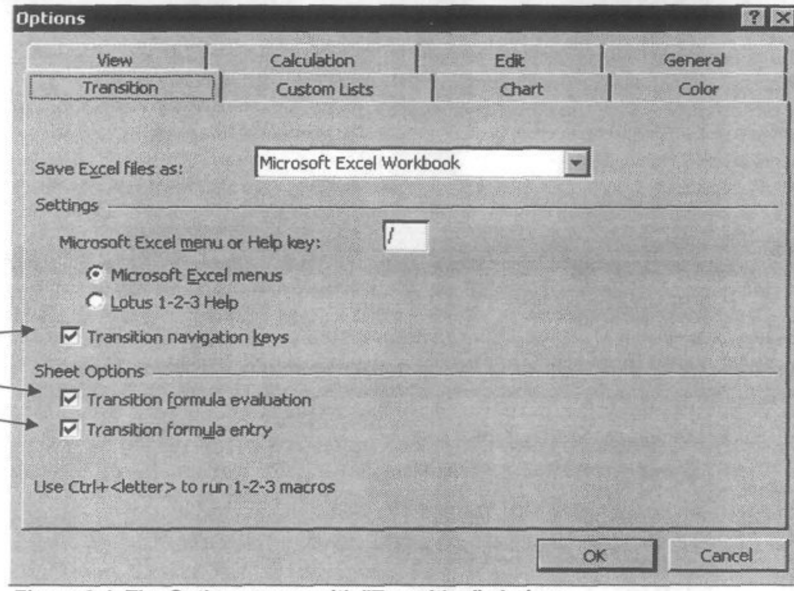

Figure 2-4 The Options menu with "Transition" choices.

Edit directly in cell
Allow cell drag and drop
Alert before overwriting cells

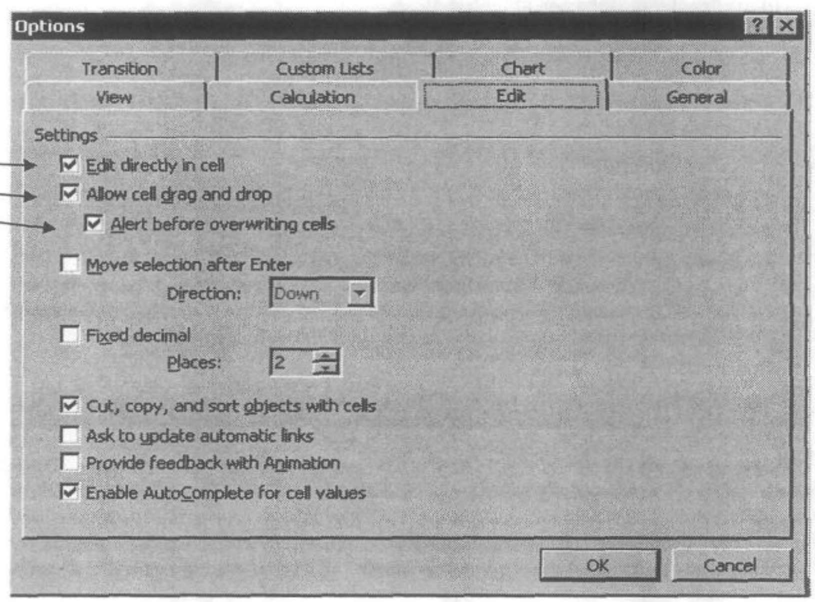

Figure 2-5 Check off "Edit" in the Options menu.

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PRINTING A DIRECTORY

Method 1

Bring up your **Windows Start** menu and select **Accessories** and then **Command Prompt**.

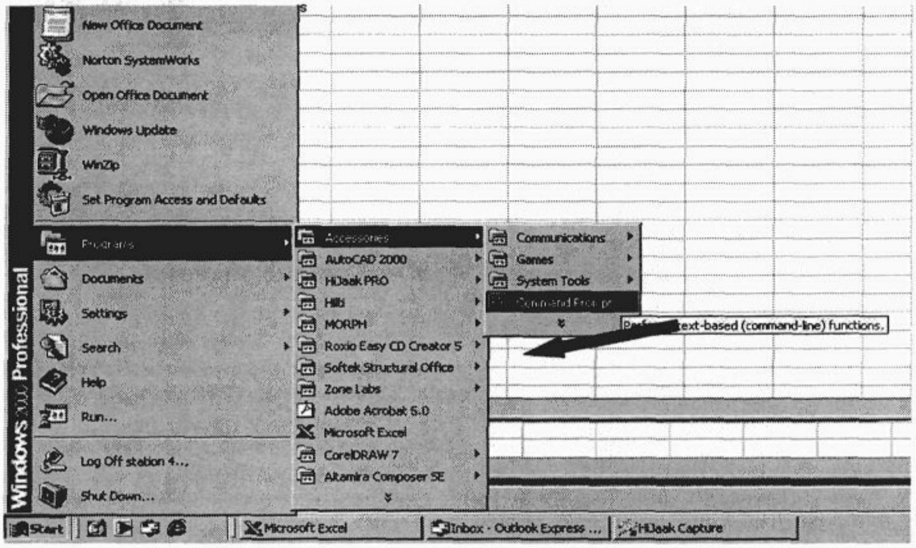


Figure 2-6 Selecting Command Prompt in the Windows Start menu.

Command Prompt brings up what is essentially an old fashioned **DOS** window.

Type in **cd** which is the DOS command for "**change directory**." Type in the appropriate directory name.

In this case, the directory name is **#SES**. The **#** puts the directory name close to the top of the directories list. **SES** stands for *Science and Engineering with the Spreadsheet* -- the name of the manual in the early '80's.

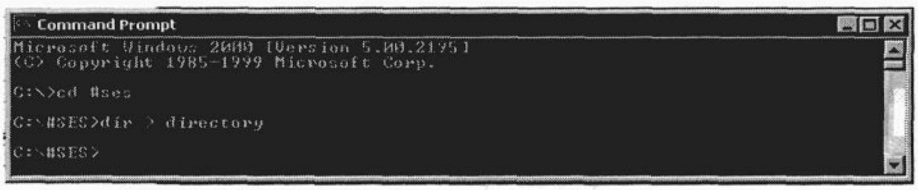
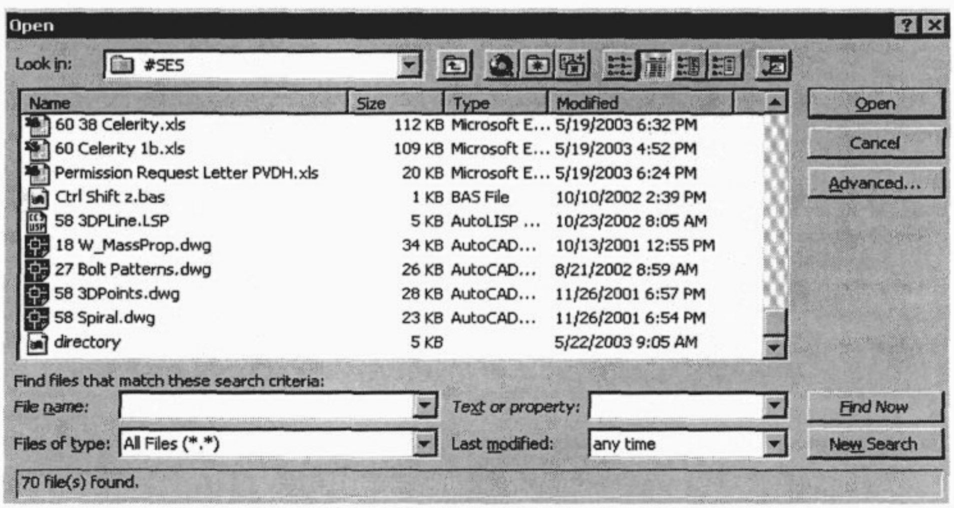


Figure 2-7 Change to the directory and save it to a file.

Type in **dir > directory**
where dir is a DOS command, space, greater than sign, space, and some type of file name such as "directory."

Then hit the **[Enter]** key.



Go back to the spreadsheet and set Files of type: to **All Files (*.*)**. Find your text file and hit **[Return]**.

The * global choice symbol can also be used in locating files.

Example: 60*.xls
60 Celerity 1b.*

Figure 2-8 Select the "directory" file in the Excel File menu.

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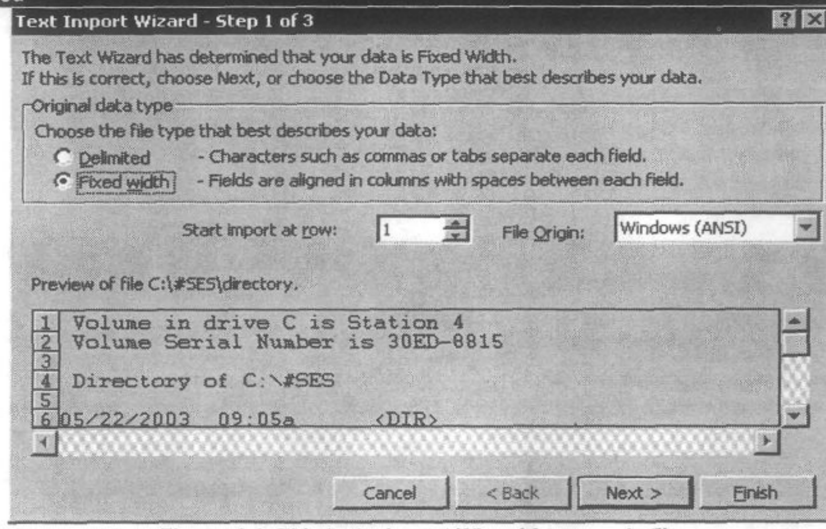
A B C D E F G H I J K L M N

PRINTING A DIRECTORY -- Continued

What you get is the **Text Import Wizard**. Make it easy on yourself and choose "**Finish**."



row 320

row 330

Figure 2-9 This is the Import Wizard for non-.xls files.

This is a text file. You can save it as an **.xls** file if you want.

This data can be sorted or processed in some other way and printed.

directory

	A	B	C	D	E	F	G
10	1/30/2003	08:54a		31,744	11	Circular Reference.xls	
11	4/12/2003	01:51p		78,336	12	Logic.xls	
12	1/31/2003	08:44a		68,096	13	DATABASE.xls	
13	2/3/2003	09:39a		339,456	14	Regression Analysis.xls	
14	2/3/2003	09:39a		27,136	15	TAKEDOWN.xls	
15	2/3/2003	09:39a		73,728	16	POLE.xls	
16	4/12/2003	01:57p		175,104	17	Moment Distribution.xls	
17	5/21/2003	01:44p		251,904	18	Numerical Integration.xls	
18	10/13/2001	12:55p		34,358	18	W_MassProp.dwg	
19	10/13/2001	12:47p		729	18	W_MassProp.mpr	
20	2/2/2003	07:00p		245,248	19	Matrix Math.XLS	
21	5/1/2003	08:39p		146,944	20	Matrix Methods.XLS	
22	4/12/2003	01:36p		376,832	21	Matrix Frame and Truss.xls	

Figure 2-10 This is a partial display of the "directory" file. row 350

Method 2

If what you need is a list of what is on a CD Rom, for instance, select the directory using **Windows Explorer** and hit **[Print Screen]**. Go into the spreadsheet and paste with **[Ctrl] [v]**. You have a picture that can be cropped with the drawing tool and printed.

cropping icon

Figure 2-11 The Picture Editing menu.

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ENGINEERING with the SPREADSHEET

_2 Tips.xls

A B C D E F G H I J K L M N

USING LINKS

Linking spreadsheets together does have its advantages. Large spreadsheets are often better when broken up into smaller modules.

Linking can also be accomplished with the cut and paste command. Cut a formula from a spreadsheet and paste it into another spreadsheet.

Some links become obsolete or are accidentally introduced into the spreadsheet. Every time the file is loaded you get a flag asking you if you want to update the links.

row 380

A link can be cleared by erasing/clearing the cell in which the link is located. Sometimes, though, these links are hard to find.

Linking Spreadsheets

This example uses this file and a file named **_2 Tips links.xls**.

To link: 1

row 390

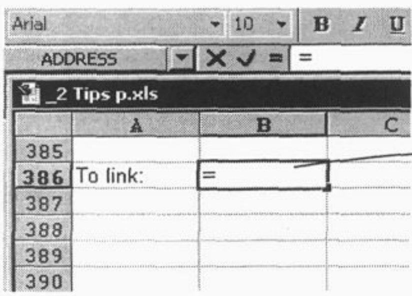
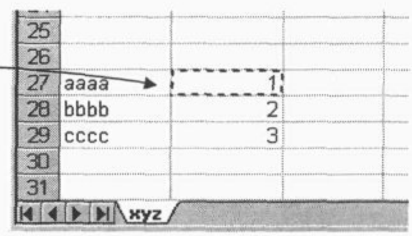


Figure 2-12 Enter an equals "=" sign in the cell to reference another spreadsheet.



row 400

Figure 2-13 While still in the edit mode, click on the cell to be referenced in the second spreadsheet.

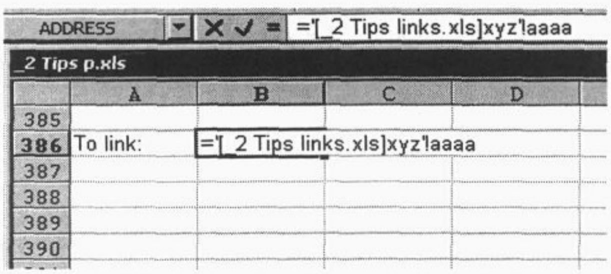
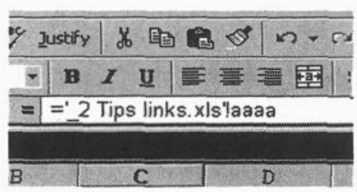


Figure 2-14 This is how the reference looks in the first spreadsheet while still in the edit mode.



row 410

Figure 2-15 Press [Return] to get this in the edit window.

Link: 1

row 420

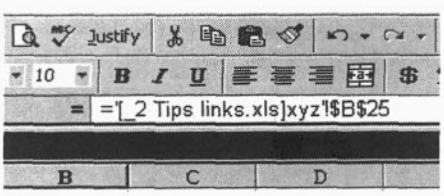


Figure 2-16 A referenced cell without range names will look like this in the edit window.

row 430

ENGINEERING with the SPREADSHEET

A B C D E F G H I J K L M N

REMOVING LINKS

If an unwanted link is hard to find, try this procedure in the referenced file:

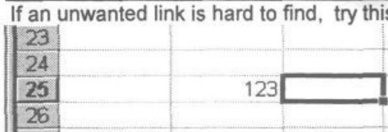


Figure 2-17 Move a range of cells into the referenced cell of the second spreadsheet.

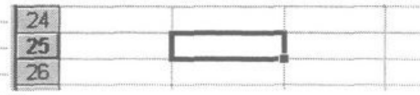


Figure 2-18 Press "OK" to clear the caution flag and get this.

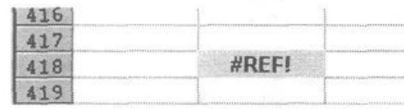
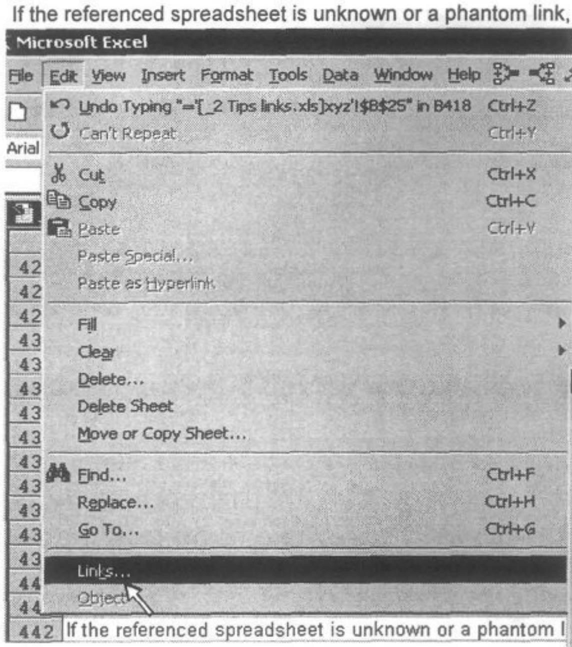


Figure 2- 19 The referencing cell will look like this making it easier to find.

row 440

If the referenced spreadsheet is unknown or a phantom link, use this procedure:



row 450

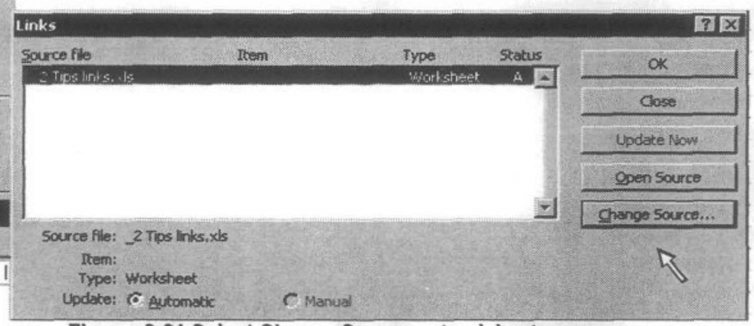
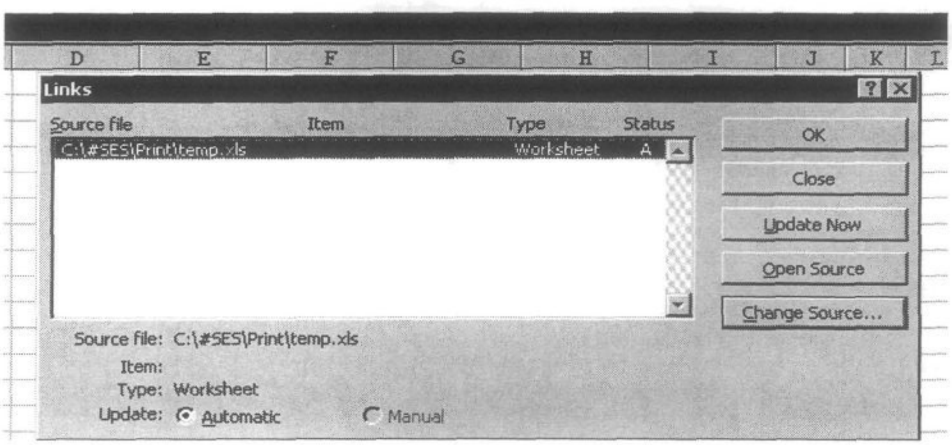


Figure 2-20 Go to the Edit menu and click on Links.

Figure 2-21 Select Change Source... to pick a temporary file as the referenced file.

row 470



row 480

Figure 2-22 This is the new referenced file. Click "OK" in the Links window. Delete rows or columns in the temporary file to destroy the referenced cell(s).

row 490

REMOVING LINKS -- Continued

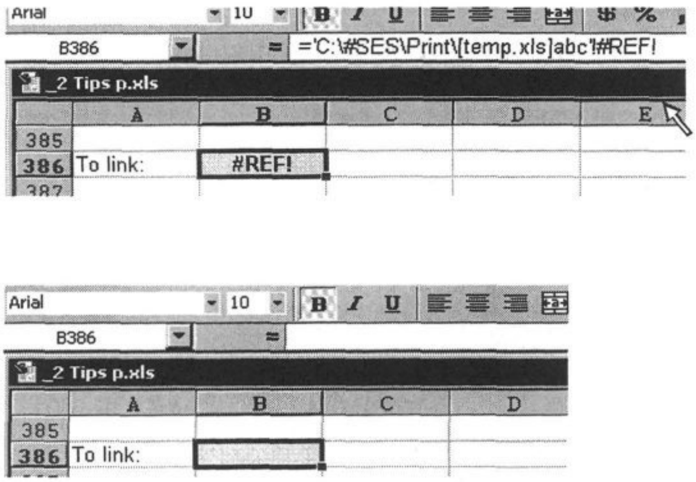


Figure 2-23 Erase/clear all of the #REF! cells. Cells that are not cleared will maintain a reference to the temporary file.

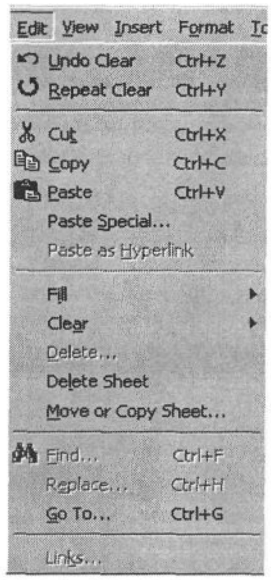


Figure 2-24 The Edit, Links dropdown menu will look like this when all links are removed.

row 500

row 510

row 520

Another method of finding links is to invoke the **Edit** menu and **Find** command. Enter a likely file location such as **C:**, your root directory. The find command will look for words and formulas containing this object. In this case it finds the cell linking this page number to the preceding chapter.

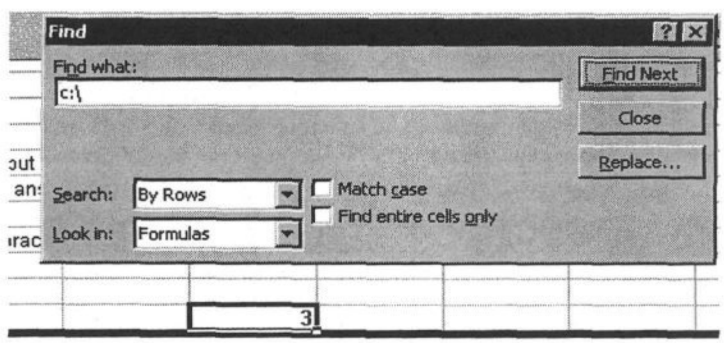


Figure 2-25 Enter a probable, global address to find the cell linked to another spreadsheet.

Figure 2-26 The Formula Bar displays the results of the Find comand.

row 550

HEADERS

The header is usually 9 or 10 rows deep. This particular template is setup to print at 80%. The typical page of information is 60 rows deep. The bottom page break may have to be adjusted up when super and subscripting are used. Adjust up or down by increments of 10 rows.

To set a repeating header:

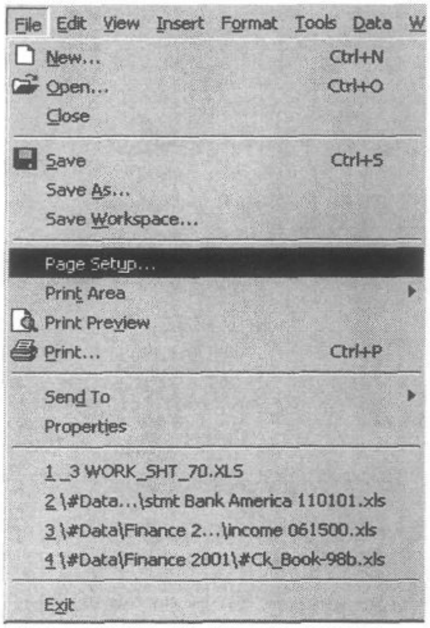


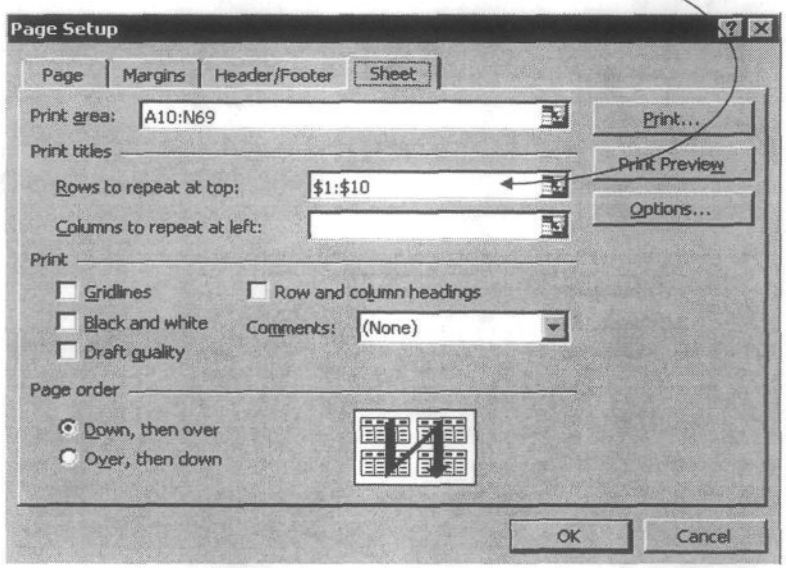
Figure 3-1 The File drop down menu.

row 20

Click on File and then Page Setup

In Sheet, click on Rows to repeat at top:

row 30



row 40

row 50

Figure 3-2 Rows to repeat at the top of the Page in the Setup menu.

The header repeats on each page and includes the alpha (alphabet) row which identifies each column. The alpha row is set to a 8 sized font. The row numbers on the right side of the page and the alpha column labels are very useful in phone conversations.

When you set the print range, do not include the header. The header prints automatically.

The logo in the header can be generated in AutoCAD or native spreadsheet drawing tools. Logos using native tools will print much faster than logos generated in AutoCAD but the AutoCAD logos can be resized and stretched more easily. row 60
This is because logos made up of Excel lines and text do not resize together.

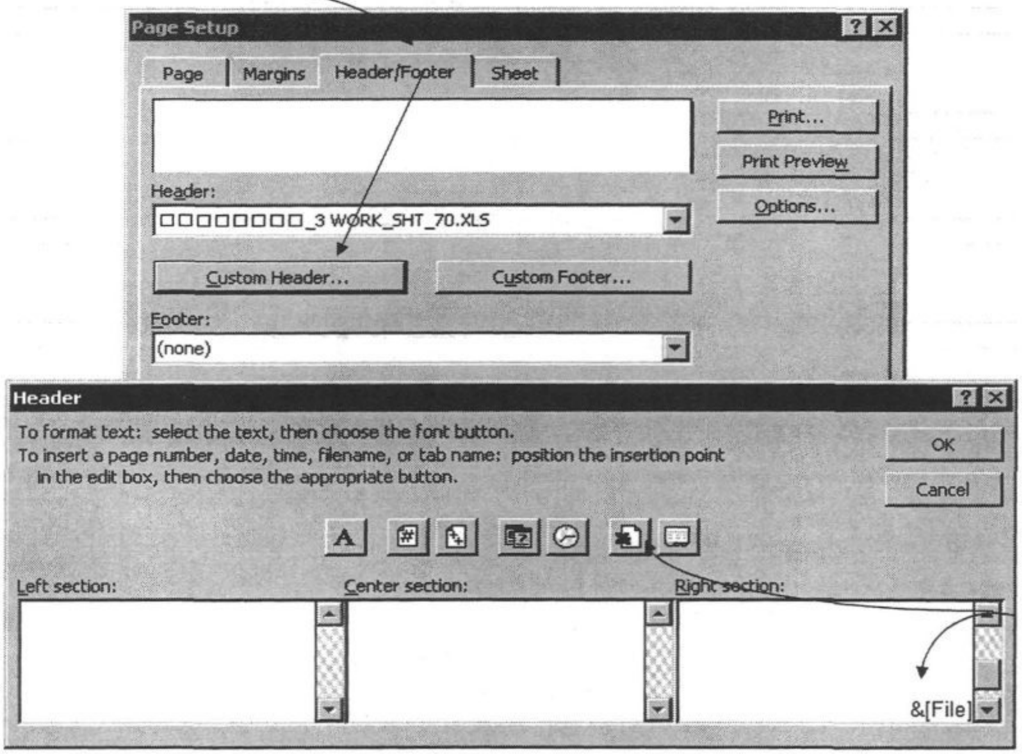
Pages that measure a total of 70 to 80 lines deep by 14 columns wide seem to work best for containing a module of calculations. You must weigh the amount of information included on the page versus someone else's ability to read it. Small fonts can be a nuisance.

Column width is 9 characters wide except for K, L, and M columns in an 80% print sized template. If the date stamp doesn't fit in column N, reduce it to an 8 sized font from the default 10.

row 70

DATE, TIME, AND FILE STAMPS

To place a file stamp in the header, select Header/Footer in Page Setup and click on Custom Header...



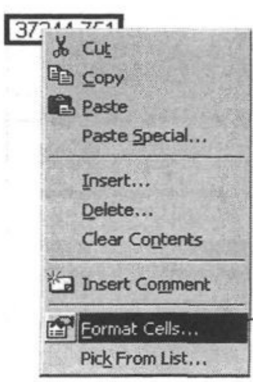
row 80

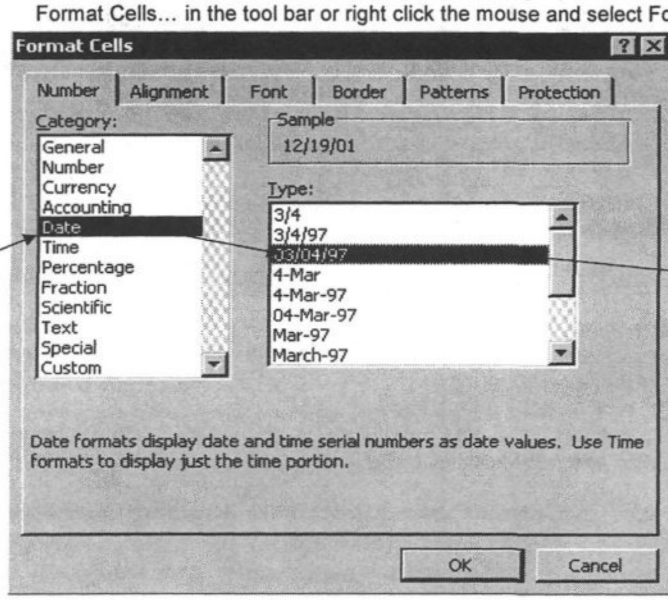
row 90

Press **[Return]** about 7 times and then click on the file identification icon.

Figure 3-3 Setting up the header.

Date and time stamps are generated with the NOW() operator. Format the operator through Format Cells... in the tool bar or right click the mouse and select Format Cells....





NOW()

row 110

The same formatting sequence applies for the time stamp.

If the date stamp doesn't fit in the column, set it to an 8 sized font.

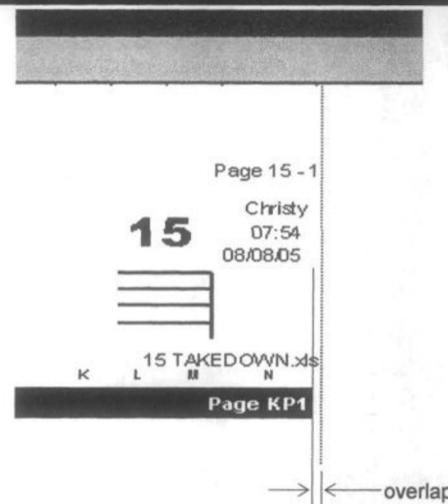
Figure 3-4 Formating for date and time.

row 130

DATE, TIME, AND FILE STAMPS -- Continued

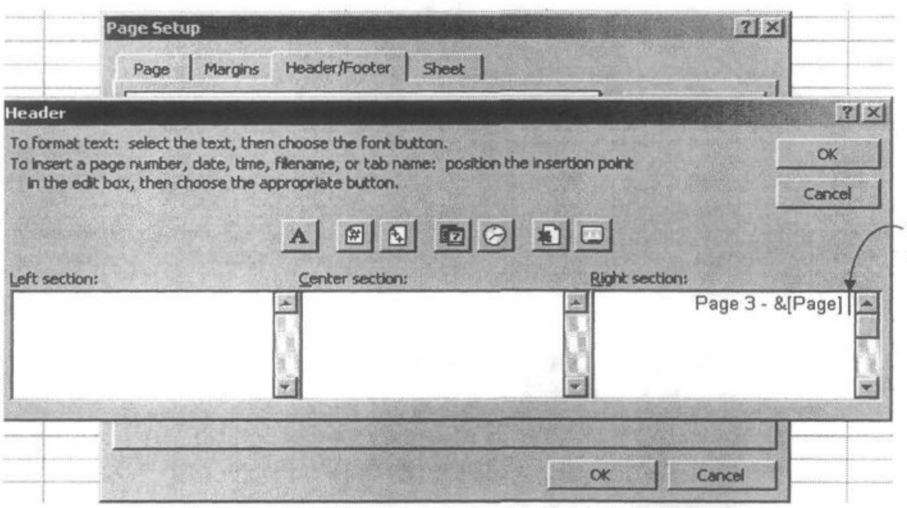
Sometimes, the custom header information overlaps the right margin. Excel doesn't let you insert a couple of spacebar spaces to move the information to the left and you can't set the margins to greater than 0.75 in setup to adjust the position of the header information.

To crowd the header information to the left, locate your cursor to the far right of the character string, press [Num Lock] on, hold down the [Alt] key, and enter 255 on the keypad. This will insert an invisible space that is about half a character wide.



row 140

Figure 3-5 The header text extends beyond the printed margin.



This is the blinking cursor to the right of the invisible spaces

row 160

row 170

Figure 3-6 Inserting blank spaces into a header character string.

row 180

row 190

_3 Worksheet_70.xls

A B C D E F G H I J K L M N

GUIDE TO ROW NUMBERS

70 ROWS per PAGE		80 ROWS per PAGE		
10		10		
60		70		
70	1150	80	1340	
130	1210	150	1410	
190	1270	220	1480	
250	1330	290	1550	
310	1390	360	1620	row 200
370	1450	430	1690	
430	1510	500	1760	
490	1570	570	1830	
550	1630	640	1900	
610	1690	710	1970	
670	1750	780	2040	
730	1810	850	2110	
790	1870	920	2180	
850	1930	990	2250	
910	1990	1060	2320	row 210
970	2050	1130	2390	
1030	2110	1200	2460	
1090	2170	1270	2530	

Figure 3-7 Lengths of 70 and 80 row pages by row number.

NOTES

The notes part of the template are located on your right hand side. They can start in column G, H, or I depending upon your style and the nature of your presentation. row 220

Notes, highlights, sketches, and photos can be hand written on your printout. If you have to revise your calculations, simply cut the handwritten part out of the voided printout and tape it onto the new printout with the easy liftoff tape or the frosted style of tape. These generally go through a copy machine without casting tape shadows on the copy. Some times the clear tape works quite well, too.

row 230

Dissect this template and the other templates in this manual to see how they were created.

row 240

row 250

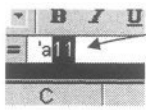
EDITING IN EXCEL

SUBSCRIPTING AND SUPERSCRIPTING

Step 1

Super and subscripting are done with editing in the cell. Input the character with the super/subscripted characters and add a blank space by hitting the spacebar.

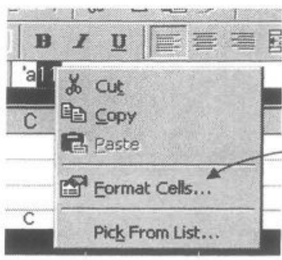
Step 2



While in the edit mode, highlight the characters to be subscripted (in this case) and right-click the mouse button.

row 20

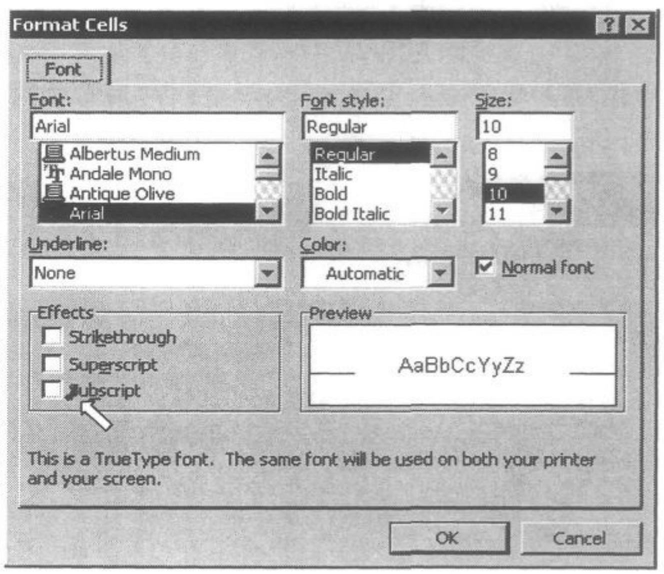
Step 3



Choose Format Cells...

row 30

Step 4



row 40

Highlight Subscript with your cursor and click the left mouse button

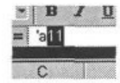
row 50

This is the result -- the row becomes deeper automatically

Figure 4-1 The pull down menu for super and subscripting.

row 60

row 70



ENGINEERING with the SPREADSHEET

A B C D E F G H I J K L M

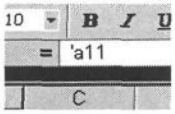
EDITING SUPER/SUBSCRIPTS AND OTHER CHARACTERS

To change a_{11} to a_{12} do the following:

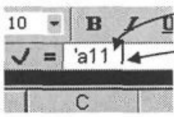
Copy the character to the next cell and edit the sub/superscript. Hit Edit **[F2]** and then highlight the character with your cursor. Type in the new character (over the top of the *old character*) and hit **[Return]**.

a_{11} ← The notation to be edited

Step 1



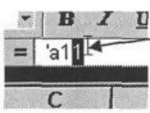
Step 2



← the space beyond the character (space bar)

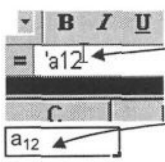
← cursor mark

Step 3



← highlight the character to be replaced

Step 4



← this is the replacement character

← the edit cell will look like this during the replacement process

a_{12}

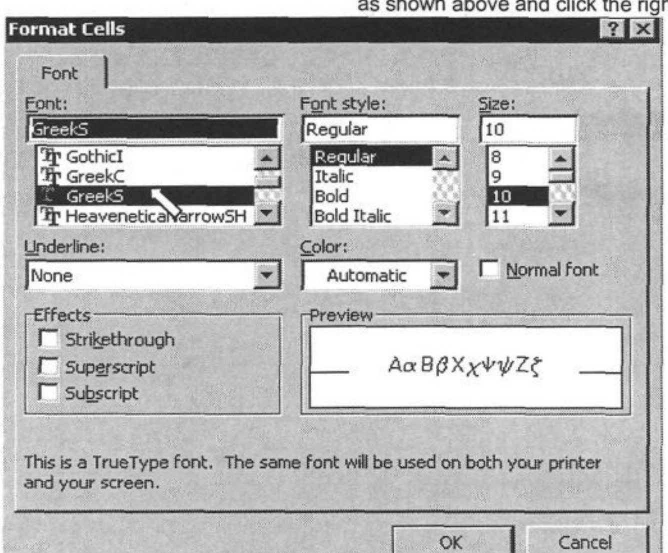
a_{12} ← this is the finished product

Figure 4-2 Changing super and sub scripting.

FORMATTING ENGLISH CHARACTERS TO GREEK MATH CHARACTERS

To change a to a:

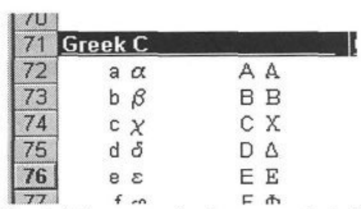
a_{12} ← Put your cursor on the cell to be reformatted. In the edit bar, highlight the "a" as shown above and click the right mouse button to display the drop down menu.



In Font: scroll down the to font set that you need and highlight the font with a left click. Then click OK.

If the character prints too lightly, try making it bold or choose another character font.

Greek letters can be found in the "Symbols" file.

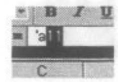


Math and Greek letters can also be generated with Windows character map. See the explanation belo

NOTE: SymbolSH will print a darker a. The fo *also be selected in the tool bar on the u* left hand side of the screen worksheet.

a_{12} ← this is the finished product

Figure 4-3 Formatting for Greek symbols.

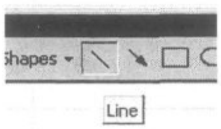


MAKE YOUR OWN MATH OPERATORS

People unfamiliar with spreadsheets are sometimes puzzled by spreadsheet notation. An example of this is:

2^0.5 = 1.41 This is a simple relationship showing that square root of 2 is 1.41

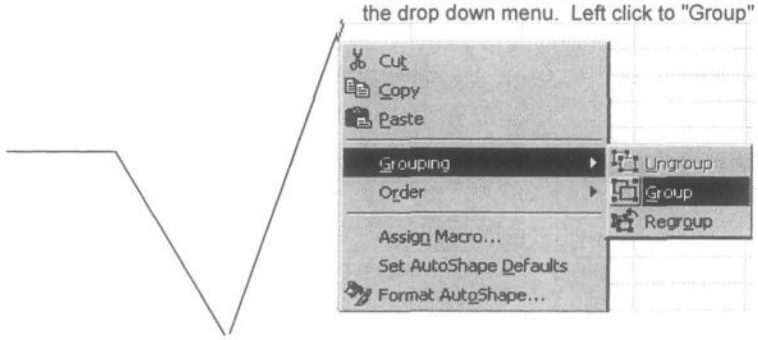
Making the square root bracket is done as follows:



In the Drawing toolbar, double left click on the line symbol. row 140

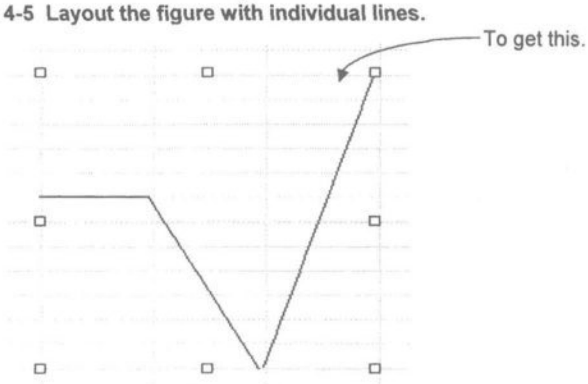
Figure 4-4 Choose "line" from the drawing toolbar.

Draw in this symbol as shown. To "Group" the lines, hold down the shift key and left click on each line. Hold your pointer on one of the highlighted lines and then right click to get the drop down menu. Left click to "Group" the lines.



row 150

Figure 4-5 Layout the figure with individual lines. row 160



row 170

Figure 4-6 Grouping lines to create a figure.

$\sqrt{}$ ← Reduce the size of your symbol to fit your needs.

$\sqrt{2}$ = 1.41 ← Add a horizontal line of the needed length. row 180

Figure 4-7 Re-size the large figure to suit your needs.

By the way -- for the "is-less-than-or-equal-to" symbol, simply underline the < or >. In a spreadsheet formula this looks like this ⟶ 1 ≤ 2. You can also get these symbols from the symbols chapter. ⟶ 1 <= 2
Be sure to check your printout -- what you see is not always what you get.

This symbol was drawn in Excel

See the Symbols Chapter of this manual for other methods

row 190

ADJUSTABLE TEXT -- Text Justify

The text justify button in EXCEL justifies text along an even left side border.
This button must be obtained from: Tools
Customize...
Edit
Select Justify, right click and drag it up to the tool bar(s).

Justifying with this command will drop individual formatting.

row 200

To remove a button from a tool bar open Tools, Customize..., and then right click on the button and drag it back to the Customize... popdown window.

Wrapping within Single and Merged Cells

Another method which is particularly useful in databases is the Wrap text command.
This can be done in a single cell which can be sorted in a database such as a phone list:

The quick
brown fox
jumped
over the
lazy dog's
back.

or in a group of merged cells which cannot be sorted in a database:

row 210

The quick brown fox jumped over
the lazy dog's back.

Choose Format, Cells..., Alignment from the tool bar or right click your mouse and choose Format Cells... from the popup menu.
You'll find Merge and Wrap text here under Alignment. Be sure that your pointer is over the box when you right click.

Adjustable / Referenced Text in a Drawing

The drawing to the right is an AutoCad 2000 3D view of a Simpson HD6A holddown. It was copied out of a view port in paper space and pasted with the command: Paste Special, Picture (enhanced metafile).

row 220

From the drawing tool button pop down tool bar select the text box. Place the text box where you want it in the drawing. Then place your pointer in the edit row just below the tool bars and type in an equals = symbol. Then point to the text that will change -- in this case we call it Text_1 and it is located in column B.

Text_1 **The quick brown fox**

row 230

The text box can be formatted to have no borders or background. The text can be changed through user input or as the result of a calculation.

Text_2 **jumped over the lazy dog's back.**

multiply	**12**
by	**2**
to get	24

row 240

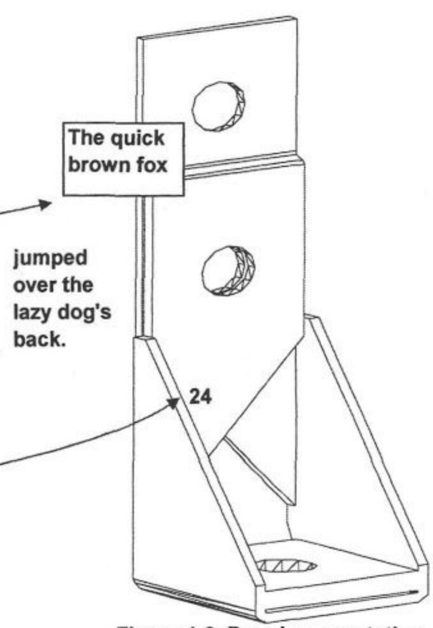
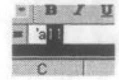


Figure 4-8 Drawing annotation.

row 250



A B C D E F G H I J K L M N

CONDITIONAL FORMATTING

Conditional formatting is a way to flag answers, make non-pertinent information fade into the background, and to make tables easier to read.

For example, input 0's and negative or positive numbers into this table where the 0's are simply place holders in a matrix:

due to unit displacement in coordinate

a = independent displacements of elements			x_1 ↑	x_2 →	x_3 ↶	x_4 ↑	x_5 →	x_6 ↶
	AB	v_1	1	0	0	0	0	0
		v_2	0	1	1	0	0	0
		v_3	0	1	1	0	0	0
	BC	v_1	0	1	0	0	1	0
		v_2	1	1	1	1	0	1
		v_3	1	1	1	1	0	1
	CD	v_1	0	0	0	1	0	0
		v_2	0	0	0	0	0	1
		v_3	0	0	0	0	0	1

row 260

Figure 4-9 Flagging with conditional formatting.

In spreadsheet matrix math, an empty cell will cause the entire process to fail whereas a 0 or a number will give a result (providing it is the right input). row 270

To invoke conditional formatting, click on the Format menu item

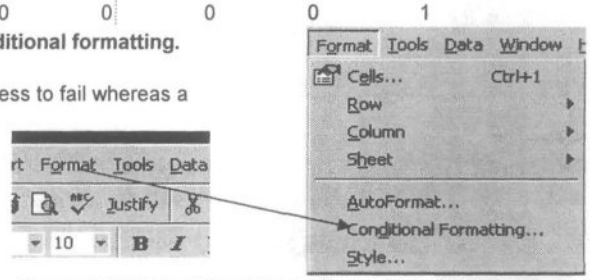
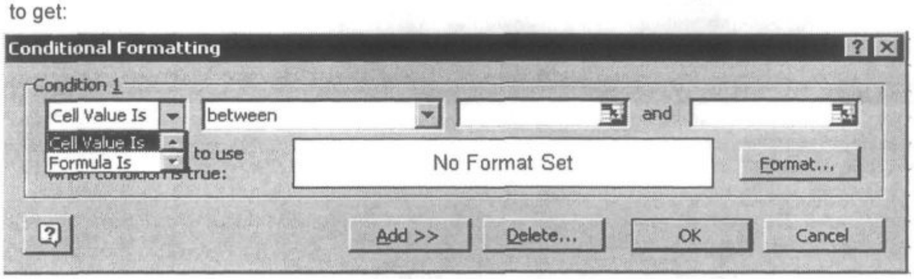


Figure 4-10 Select Conditional Formatting from the Format drop down menu.

to get: row 280



row 290

The above table was formatted like this:

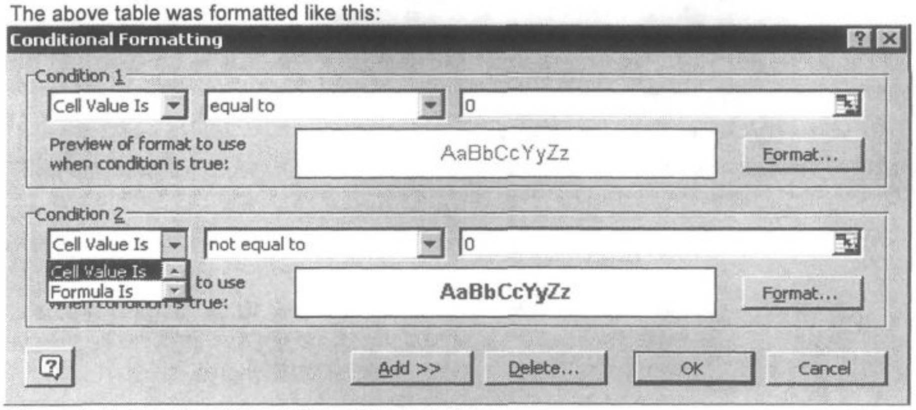


Figure 4-11 The Conditional Formatting window.

You can have three conditional formats. There are other examples of conditional formatting throughout this manual and disk.

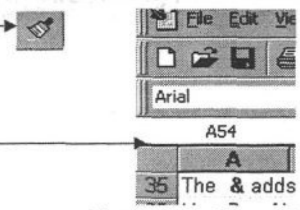
row 300

row 310

FORMATTING A NEW SHEET OR TAB

Format a new sheet by double clicking the Format Painter button.

Click the top left corner of the rows and columns cell of the spreadsheet.
Double click or press **[Escape]** to turn the format painter button off.



row 320

Figure 4-12 Formatting a sheet with the Format button.

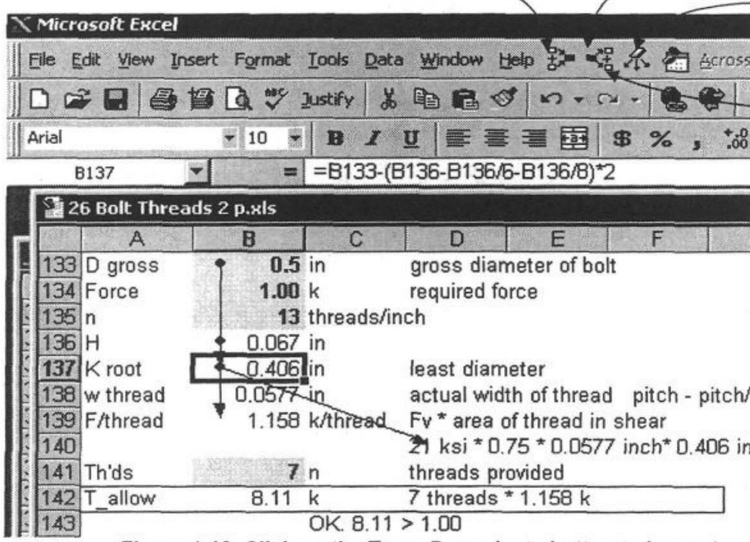
Within a sheet, single click the format painter button to copy a format to one other cell. Double click the format painter button to format copy a format to several cells.

THE TRACE COMMAND

The trace commands are used to determine what inputs an equation is using and what other equations depend upon it.

Trace Precedents
Trace Dependents
Remove All Arrows

row 330



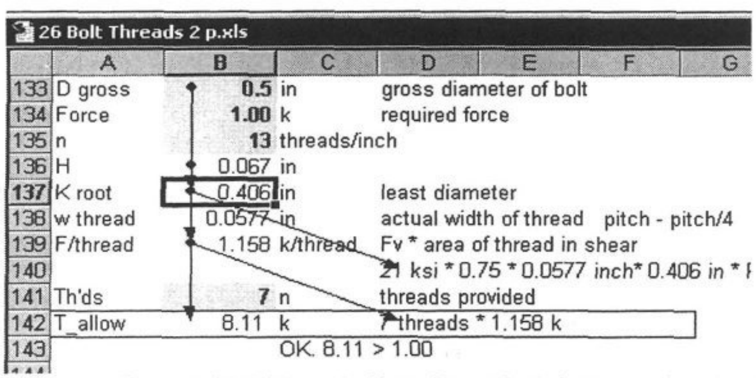
These commands can be taken from the Tools Customize Commands pulldown menu and placed in the top menu row.

row 340

Precedent
Equation
Dependent

row 350

Figure 4-13 Click on the Trace Precedents button to locate inputs to the formula and click on the Trace Dependents button to locate results.

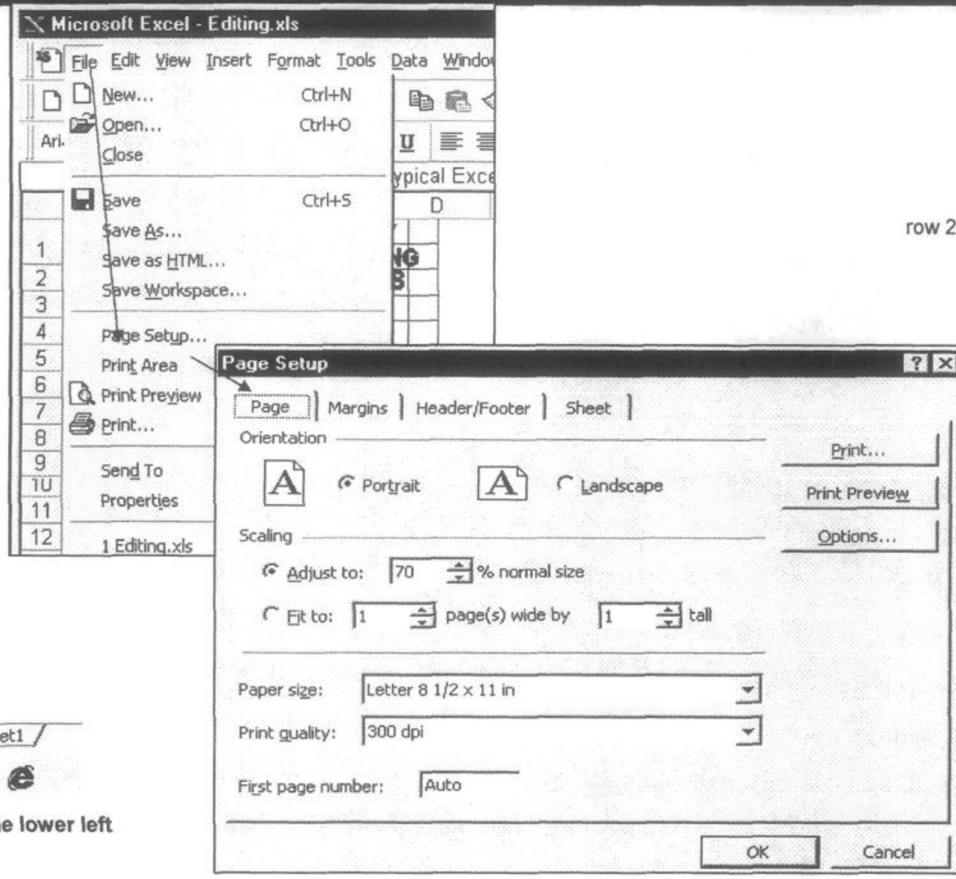


row 360

Figure 4-14 Click on the Trace Dependents button again to locate results of the results.

row 370

OVERVIEW



This template uses typical Excel row and column width and height with Arial font at a 10 pitch. It is printed out at 70% in the page set-up menu. Review other features regarding margins, header, and page and tab identification in the header.

row 20

Column width is nine except for columns K, L, and M.

Tabs

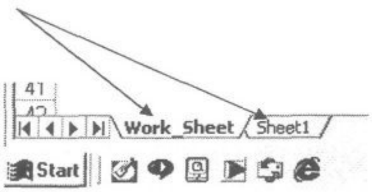


Figure 5-1 Spreadsheet tabs in the lower left corner of your screen.

Figure 5-2 The File menu system.

This worksheet yields the equivalent of a 132 character per line format in terms of the old dot matrix printers. The overall worksheet is 80 rows deep on an HP LaserJet printer. Although this is somewhat condensed compared to a typical letter page, it seems to work well to create modules of information or calculations.

row 50

Included with this set of files is a worksheet that is less condensed. It yields 70 rows per page.

The row numbers to the right help greatly in telephone conversations. Rather than ask for a page number and approximate location on the page that the caller wants to know about, ask for a row number and column letter.

The row number is created through concatenation: ="row "&FIXED(CELL("row",O60),0)

Note that the cell "row" value is referenced in the next column over. Rarely do we do work in this area and, so, this value is seldom disturbed. When row labels get wiped out, simply copy one from a good sample somewhere else in the spreadsheet -- or another spreadsheet .

row 60

The logo at the top of the page is meant to be replaced by other users with their own logo(s).
The generic logo was created with Excel drawing tools but it can be drawn in AutoCAD.
Using Excel's drawing tools will create a file that uses less memory overhead and prints faster.
However, there is no good substitution for importing AutoCAD drawings into Excel for design and documentation.

Merging cells to permit larger print is not recommended because it will not copy into another spreadsheet. Use the drawing toolbar instead and click on the text box button.

row 70

A B C D E F G H I J K L M N

BOOLEAN ALGEBRA and the IF STATEMENT

Math operators <, >, =, <=, >=
Dog **3** unit
Fox **4** unit Boolean math

Result 1 logic
=Dog<Fox
3 Dog(s) < 4 Fox(s)

IF statements
Result_2 More foxes
=IF(Result,"More foxes","More dogs")

The Boolean statement may be contained within the IF statement
quantity **2** unit
2 Foxes string

formula text formula
=IF(quantity=1 , "1 Fox" , FIXED(quantity,0,TRUE) & " Foxes")

Note: it is often wise to show the formula used as range-named cells or even as cell-addresses. Another aid in constructing and reviewing spreadsheets is to show the numbers in a concatenated string.

row 80

See below for a definition of concatenation.

In this case, the IF statement uses the Boolean output of another cell to return a text statement.

To park an equation, press the **[F2]** edit key, press **[Home]** to go to the front of the equation string, and press the space bar to insert an apostrophie and create a text string.

row 90

It could also return the result of a formula within the IF statement or reference a result from outside of the statement and returned from within the IF statement.

A 1
B More foxes
C 2 Foxes
Answer More foxes

The equation using range names:

row 100

A
=Dog<Fox
B
=IF(Result,"More foxes","More dogs")
C
=IF(quantity=1,"1 Fox",FIXED(quantity,0,TRUE)&" Foxes")

=IF (A, B, C_)

row 110

EQUATION EDITING --------

Example 1 simply adds the words "The" and "fox" together in an equation. You can change the words in the highlighted input cell(s).

Input_1 **The**
Input_2 **fox**

We usually highlight input cells with bold, dark blue information into a light yellow background. This makes your work easier as well as helping other people using your spreadsheet.

The concatenated equation/string looks like this:
Output = The fox

The actual equation looks like this after it has been "parked:"
="Output = "&Input_1&" "&Input_2

row 120

The **& (ampersand)** adds strings in much the same way as the **+** adds numbers.
Use **fixed(x, n)** to convert a value to a string for concatenation:

123.4568
=fixed(B125,3)
123.457 ← this is text

row 130

A B C D E F G H I J K L M N

EQUATION EDITING -- Continued

Example 2 demonstrates the "parking" of equations.

g	**1**	unit
h	**4**	unit

Place your cursor on the cell and press the **[F2]** key to edit:
100

Your equation should look like this:
=IF(B135<B136,100,-200)

Press the **[Home]** key to go to the beginning of the equation:
=IF(B135<B136,100,-200)

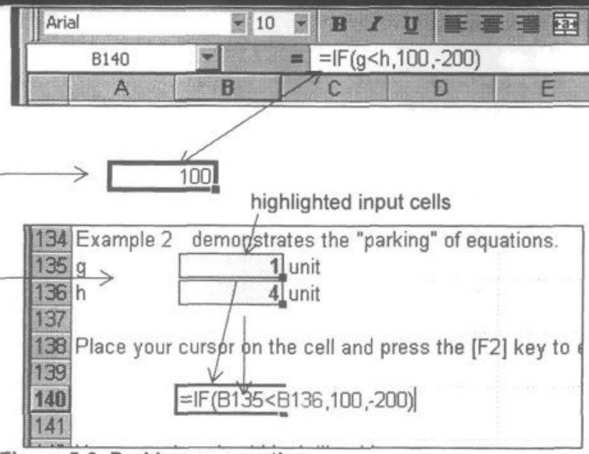


Figure 5-3 Parking an equation.

row 150

Press the space bar or insert a column before the = (equals) sign and press **[Return]** to finish parking the equation:
=IF(B135<B136,100,-200)

An equation can be reproduced in other parts of the spreadsheet by inserting a comma or space to convert it to text.
Copy the equation as required and then remove the comma to re-convert the text back to an equation.

Inserting a comma also works well to put a malfunctioning equation on hold.

ADDING EQUATIONS with JUSTIFY

row 160

fa	**4.00**	ksi
fb	**6.00**	ksi
Fa_allowed	**10.000**	ksi
Fb_allowed	**18.000**	ksi
ratio 1	0.400	
ratio 2	0.333	

Add two equations by placing one above the other.
Park the equations with a space or apostrophe:
ratio 1 =B160/B162
ratio 2 =B161/B163

row 170

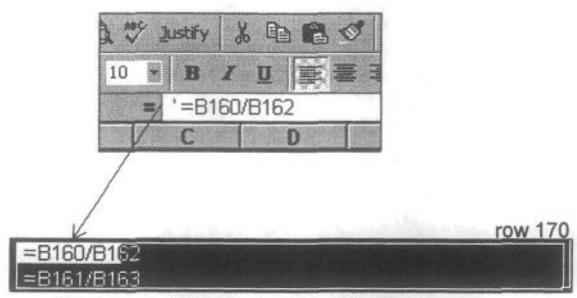
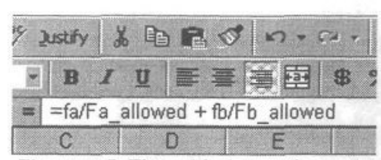


Figure 5-4 Adding equations together.

Use the justify command to create a row of text:
=B160/B162 =B161/B163

Replace the equals sign in the middle of the row and replace it with a math operator -- in this case it will be a "+".
Remove the space or apostrophe at the beginning of the row:
=B160/B162 + B161/B163
0.733

row 180



The cells referenced in the formulas were range named.

Figure 5-5 The added equations shown as range names.

Another important method of adding (combining) equations together is through concatenation. We normally think of concatenating text. Use your cursor on the cell displaying "The quick brown fox":

The quick
brown fox
=B156&B157
The quick brown fox

row 190

A B C D E F G H I J K L M N

ANOTHER EXAMPLE of PARK and CONCATENATE

An equation can be easily parked and copied without changing the references.
The following example equation(s) use numbers only.

D 2

Press the **[F2]** edit key. Press the **[Home]** key to go to the front of the equation. Press the **[Space Bar]** to insert a space and turn the equation into plain text.

=(1+1)

and row 200

E 4

convert to =(2+2)

Create this equation, = D +E , by concatenation.

=(1+1) +
=(2+2)

Add the + operator now to keep the process simple or add it later if you forget.

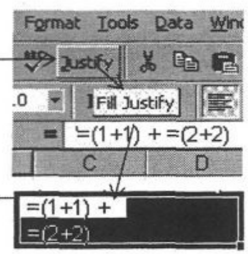


Figure 5-6 Adding equations.

Justify the range to create a text string on one row. row 210

=(1+1) + =(2+2)

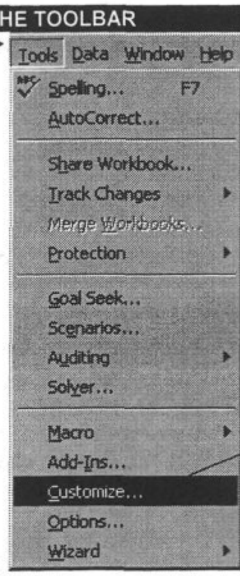
Now clean up the text by removing the = operator at mid-string and the space at the beginning of the string.

6

Inserting a space or a comma in front of an equation also works well to put a malfunctioning equation on hold.

PUTTING THE JUSTIFY BUTTON IN THE TOOLBAR

Select Tools in the toolbar. row 220



Select Customize...

Choose the Commands tab.

Then select Edit and scroll to the Justify button. Click on Justify and drag this button up to your tool bar.

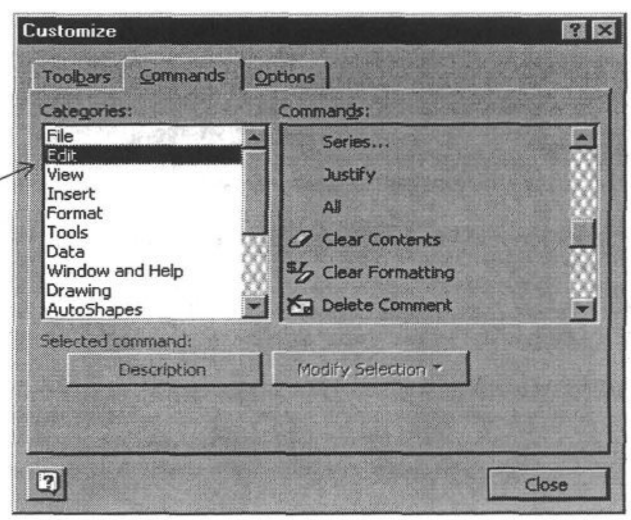


Figure 5-7 Placing commands in the tool bar.

row 250

A B C D E F G H I J K L M N

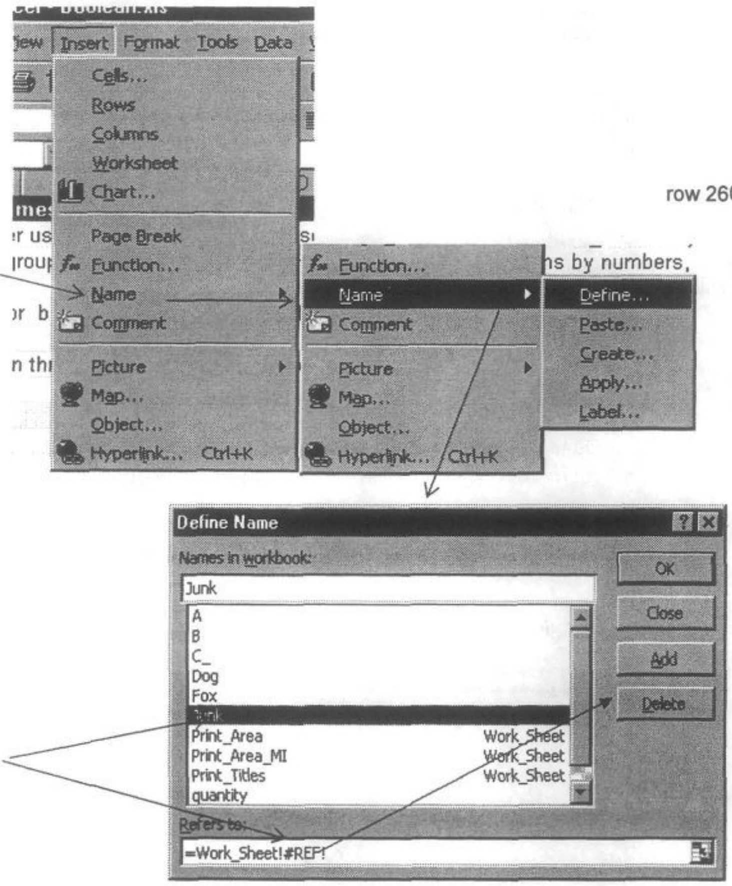
RANGE NAMES

Note: Never use a range name like **A1** (use A_1 instead)
Organize groups of inputs and calculations by numbers, alpha characters, and keyboard characters.

To look for **bad range names,** click on Insert in the tool bar, Name, Define and click on the list.

row 260

Junk 4



Scroll down through the list to look for the **#REF!** comment.

Click on Delete to remove the faulty reference.

Figure 5-8 Looking for bad range names.

row 290

Moving Around

Press the **[F5]** GoTo key to view a list of names to select from and go to or type in a spreadsheet address -- and go to that.

You can "go to" a cell address such as **B3** or to a range name. Use the # symbol in front of a range name to cause it to be listed in the beginning of the range name table.

row 300

row 310

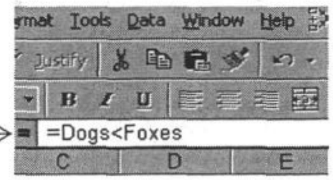
A B C D E F G H I J K L M N

Range Names in Equations

Display range names in a parked equation

Dogs	3	unit
Foxes	4	unit
Result	1	logic

Show the equation with its range names, not cell **R1C1** references.
1 parked and copied from above →



Press the **[F2]** key to edit the equation in the equation window.

row 320

Figure 5-9 Press [F2] to edit in the edit window.

Place the mouse pointer over or in front of the = sign and press the space bar.
Press **[Return]** and the equation under the cursor will turn from an equation of cell references to an equation of range name references.
This equation has been parked as text and can be copied to a comments area.

1
=Dogs<Foxes

Listing Range Names

It can help to list range names with addresses to help in checking the appropriateness of range names for inputs and values and other trouble shooting functions. row 330

Left click on the Insert button and select Define, Paste.
Select the Paste List button to create a range name list at the cursor location.

A	=Editing!$B$94
B	=Editing!$B$95
C_	=Editing!$B$96
D	=Editing!$B$195
Dog	=Editing!$B$73
Dogs	=Editing!$B$312
E	=Editing!$B$200
fa	=Editing!$B$160
Fa_allowed	=Editing!$B$162
fb	=Editing!$B$161
Fb_allowed	=Editing!$B$163
Fox	=Editing!$B$74
Foxes	=Editing!$B$313
g	=Editing!$B$133
h	=Editing!$B$134
Junk	=Editing!#REF!
Print_Area	=Editing!$A$10:$N$489
Print_Area_	=Editing!$A$291:$N$320
Print_Titles	=Editing!$1:$9
quantity	=Editing!$B$86
Result	=Editing!$B$76

row 340

row 350

Figure 5-10 The range name list.

row 360

row 370

A B C D E F G H I J K L M N

FILL -- DRAG FROM BEGINNING NUMBERS TO GET A TREND

The original Lotus 1-2-3 /Fill command has been replaced with the drag method of creating a series of numbers in a row or column. For instance: start with 1 and 2,

1
2
3
4
5
6
7 row 380
8
9
10
11
12

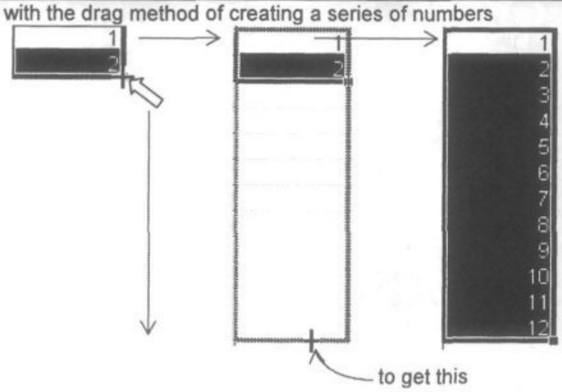


Figure 5-11 The fill operation using "drag."

Samples of the "fill in a series" command

1 start	1 start	1 start	2 start	row 390
3	4	1.1	4	
5	7	1.2	16	
7	10	1.3	32	
9	13	1.4	39	
11	16	1.5	49.2	
13	19	1.6	59.4	
15	22	1.7	69.6	
17	25	1.8	79.8	
19	28	1.9	90	
21	31	2	100.2	row 400
23	34	2.1	110.4	

To develop a trend without using the fill drag command, enter a formula

	0		2		
=B404+3	3	=G404*2	4		
	6		8		
	9		16		
	12		32		
	15		64		row 410
	18		128		
	21		256		
	24		512		
	27		1024		
	30		2048		
	33		4096	← this is binary precision	

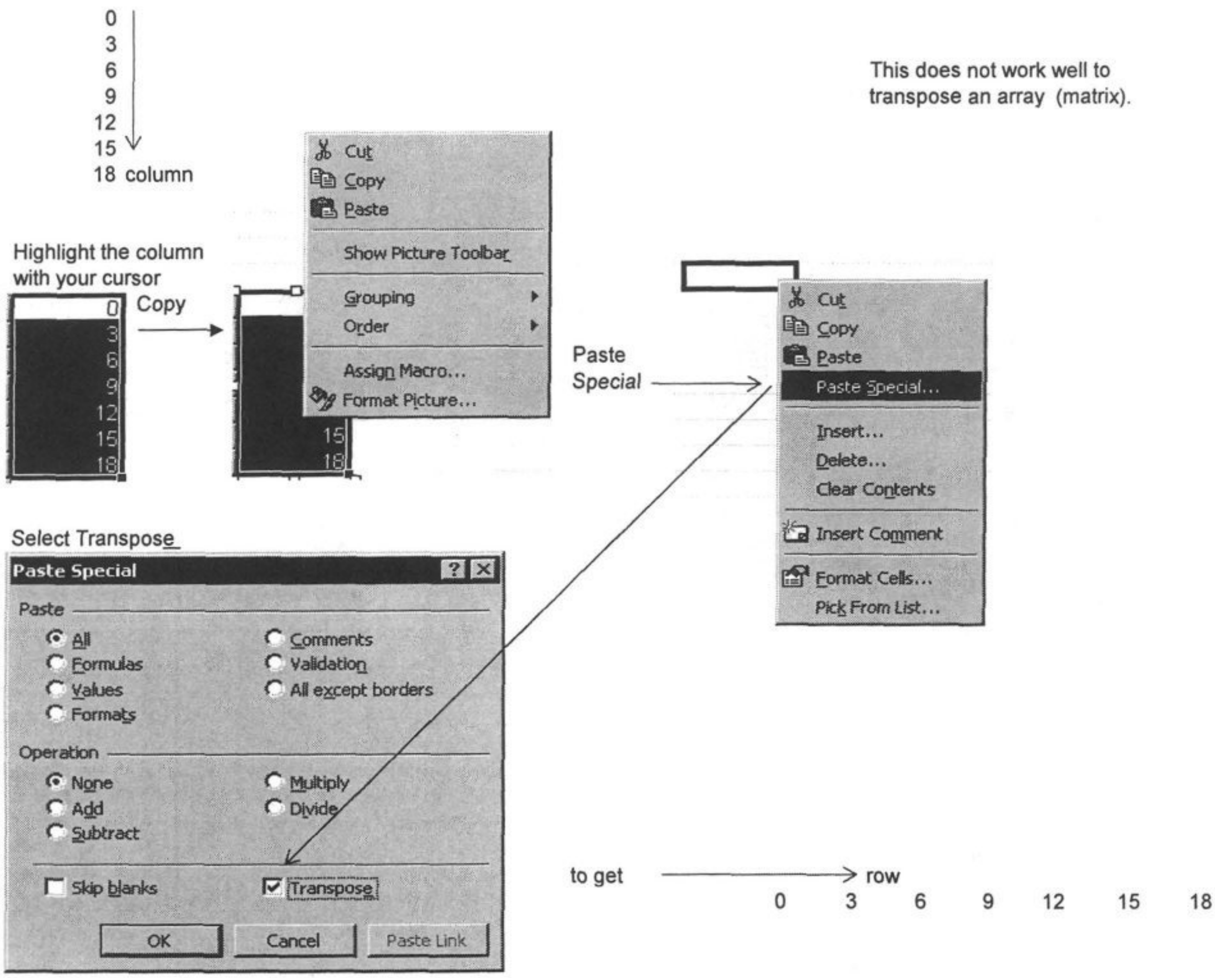
See also Edit Fill Series

row 420

row 430

TRANSPOSE -- COLUMN to ROW, ROW to COLUMN

This is an obscure - yet useful command. Say that you have entered data in a column that you should have entered into a row instead. To switch data from a column to a row:



row 440

row 450

row 460

row 470

Figure 5-12 Transposing a column of numbers to a row.

To transpose a matrix array:

	1	2	3	4	5
1	0	0	1	0	0
2	0	1	0	-1	0
3	0	0	0	0	1
4	1	0	0	0	0
5	0.7071	0	0	-0.7071	0.7071
6	0	0.7071	0.7071	0	0

manually transposed numerical array:

	1	2	3	4	5	6
1	0	0	0	1	0.707	0
2	0	1	0	0	0	0.7071
3	1	0	0	0	0	0.7071
4	0	-1	0	0	-0.707	0
5	0	0	1	0	0.707	0

paste special transpose:

	1	2	3	4	5	6
1	0	0	0	1	0.7071	0
2	0	1	0	0	0	0.7071
3	1	0	0	0	0	0.7071
4	0	-1	0	0	-0.7071	0
5	0	0	1	0	0.7071	0

row 490

_6 Symbols.xls

Symbol (A B)	(C D)	Symath (E F)	(G H)	Symap (I J)	(K L)	SymbolSH (M N)	(O P)	Symeteo (Q R)	(S T)
a α	A A	a	A A	a	A A	a a	A A	a	A ·
b β	B B	b	B B	b	B B	b b	B B	b \	B ·
c χ	C X	c	C X	c	C X	c c	C X	c ╲	C ·
d δ	D Δ	d	D Δ	d	D Δ	d d	D Δ	d –	D ▴
e ε	E E	e	E E	e	E E	e e	E E	e ⁄	E ▪
f ϕ	F Φ	f	F Φ	f	F Φ	f f	F Φ	f	F ◣
g γ	G Γ	g	G Γ	g	G Γ	g g	G Γ	g ˎ	G ^
h η	H H	h	H H	h	H H	h h	H H	h ◜	H ⌒
i ι	I I	i	I I	i	I I	i i	I I	i ◟	I ◠
j φ	J ϑ	j	J ϑ	j	J ϑ	j j	J ϑ	j ◞	J ◡
k κ	K K	k	K K	k _	K K	k k	K K	k ◝	K ◡
l λ	L Λ	l	L Λ	l ⌒	L Λ	l l	L Λ	l ◡	L ›
m μ	M M	m _	M M	m ⌒	M M	m m	M M	m (	M ›
n ν	N N	n _	N N	n ⌒	N N	n n	N N	n)	N ‹
o ο	O O	o /	O O	o 〰	O O	o o	O O	o ⌒	O S
p π	P Π	p \	P Π	p 〰	P Π	p p	P Π	p ≳	P ∼
q θ	Q Θ	q ⌈	Q Θ	q	Q Θ	q q	Q Θ	q ∿	Q ∞
r ρ	R P	r ⌉	R P	r	R P	r r	R P	r ≂	R ☈
s σ	S Σ	s (	S Σ	s	S Σ	s s	S Σ	s ≀	S 6
t τ	T T	t)	T T	t	T T	t t	T T	t ℓ	T —
u υ	U Y	u (	U Y	u	U Y	u u	U Y	u ∝	U ╱
v ϖ	V ς	v)	V ς	v	V ς	v v	V ς	v ϒ	V
w ω	W Ω	w |	W Ω	w	W Ω	w w	W Ω	w ℘	W ╲
x ξ	X Ξ	x ʃ	X Ξ	x	X Ξ	x x	X Ξ	x φ	X —
y ψ	Y Ψ	y	Y Ψ	y	Y Ψ	y y	Y Ψ	y φ	Y ⁄
z ζ	Z Z	z	Z Z	z	Z Z	z z	Z Z	z •	Z /
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	% %		% %		% %		% %		% %
	$ ∃		$ ∃		$ ∃		$ ∃		$ $
	$ ∃		$ ∃		$ ∃		$ ∃		$ $
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	@ ≅		@ ≅		@ ≅		@ ≅		@ @
	! !		! !		! !		! !		! !
	~ ~		~ ~		~ ~		~ ~		~ ~
	% %		% %		% %		% %		% %
	* *		* *		* *		* *		* *
	& &		& &		& &		& &		& &
	^ ⊥		^ ⊥		^ ⊥		^ ⊥		^ ⌢
	% %		% %		% %		% %		% %
	$ ∃		$ ∃		$ ∃		$ ∃		$ $
	# #		# #		# #		# #		# #
	@ ≅		@ ≅		@ ≅		@ ≅		@ @
	! !		! !		! !		! !		! !
	~ ~		~ ~		~ ~		~ ~		~ ~

Table 6-1 Symbol, Symath, Symap, SymbolSH, and Symeteo row 70

_6 Symbols.xls

Greek C		Greek S			Script S	
a α	A A	a α	A A	alpha	a a	A A
b β	B B	b β	B B	beta	b b	B B
c χ	C X	c χ	C X	chi	c c	C C
d δ	D Δ	d δ	D Δ	delta	d d	D D
e ε	E E	e ε	E E	epsilon	e e	E E
f φ	F Φ	f φ	F Φ	phi	f f	F F
g γ	G Γ	g γ	G Γ	gamma	g g	G G
h η	H H	h η	H H	eta	h h	H H
i ι	I I	i ι	I I	iota	i i	I I
j ∂	J ϑ	j ∂	J ϑ		j j	J J
k κ	K K	k κ	K K	kappa	k k	K K
l λ	L Λ	l λ	L Λ	lambda	l l	L L
m μ	M M	m μ	M M	mu	m m	M M
n ν	N N	n ν	N N	nu	n n	N N
o ο	O O	o ο	O O	omnicron	o o	O O
p π	P Π	p π	P Π	pi	p p	P P
q ϑ	Q Θ	q ϑ	Q Θ	theta	q q	Q Q
r ρ	R P	r ρ	R P	rho	r r	R R
s σ	S Σ	s σ	S Σ	sigma	s s	S S
t t	T T	t t	T T	tau	t t	T T
u u	U ϒ	u u	U ϒ	upsilon	u u	U U
v v	V ∇	v v	V ∇		v v	V V
w w	W Ω	w w	W Ω	omega	w w	W W
x x	X Ξ	x x	X Ξ	xi	x x	X X
y y	Y Ψ	y y	Y Ψ	psi	y y	Y Y
z z	Z Z	z z	Z Z	zeta	z z	Z Z
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	% %		% %			% %
	$ $		$ $			$ $
	$ $		$ $			$ $
	# #		# #			# #
	@ @		@ @			@ @
	! !		! !			! !
	~ ~		~ ~			~ ~
	% %		% %			% %
	* *		* *			* *
	& &		& &			& &
	^ ^		^ ^			^ ^
	% %		% %			% %
	$ $		$ $			$ $
	# #		# #			# #
	@ @		@ @			@ @
	! !		! !			! !
	~ ~		~ ~			~ ~

Table 6-2 Greek C, Greek S, and Script S.

row 130

CHARACTER MAP

Windows Character Map Using UNICODE CHARACTERS

Click the "Start" button on the task bar and work your way through the menu system to bring up the character map.

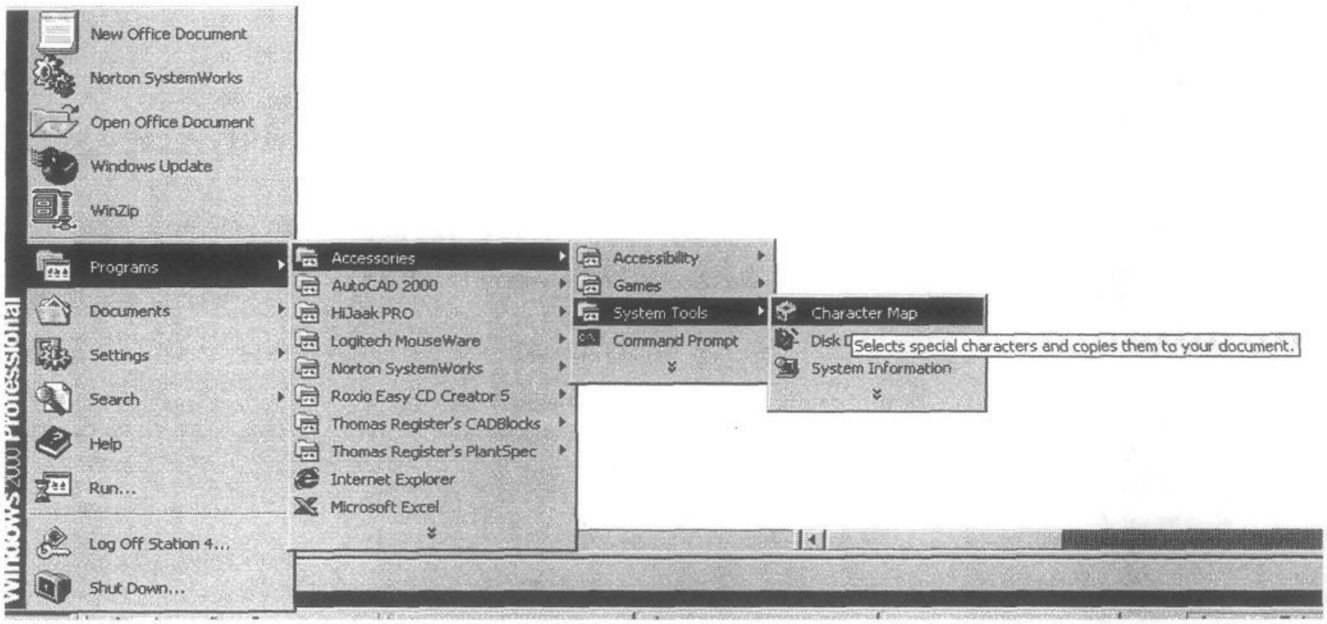
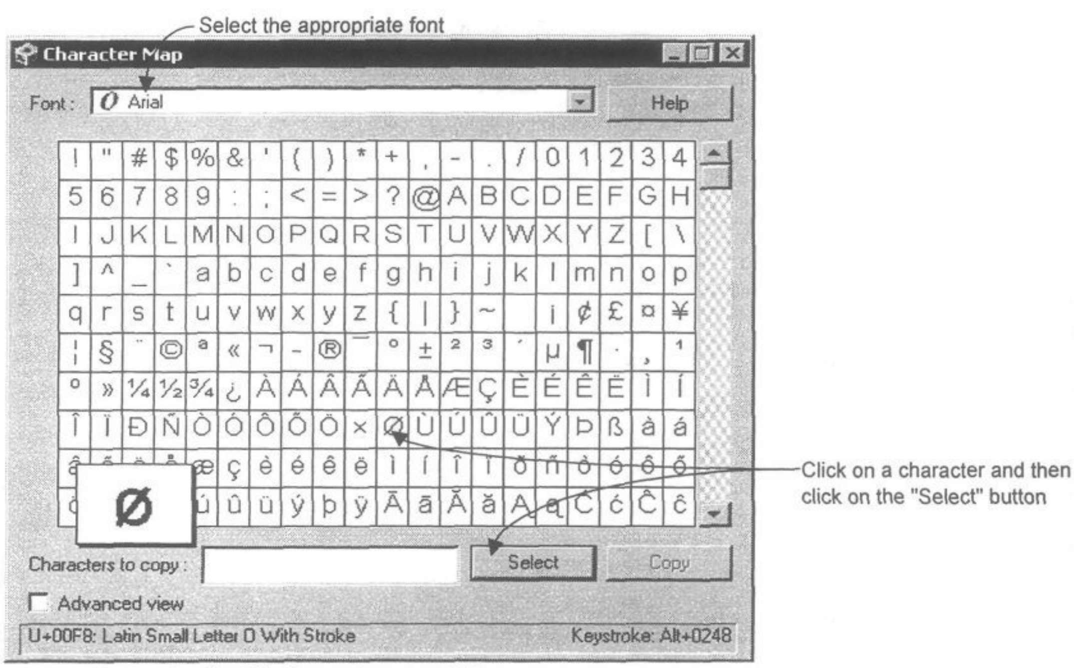


Figure 6-3 The Windows character map menu system.



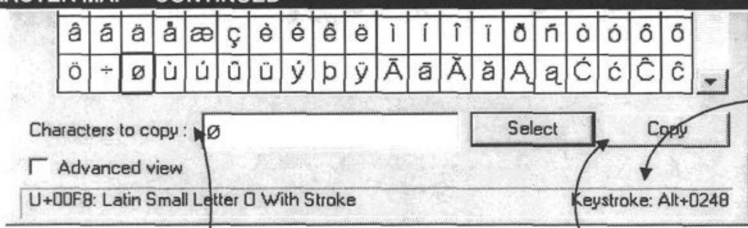
row 170

row 180

Figure 6-4 The Windows character table.

row 190

CHARACTER MAP -- CONTINUED



Note:
To input a character into a spreadsheet instead of copy clipping,
hold down the **[Alt]** *key and input* this four digit number in the right hand key pad (not the top row) to get ø.
Release the **[Alt]** *key to finish.* row 200

The character will appear in the "Characters to copy" box. ø

Press the "Copy" button and then paste *the character into the spreadsheet*

Figure 6-5 Copying a character from the character map table.

Note: The character map characters appear as the symbols they are in the edit window. Other characters such as**W** look like **W** in the edit window when SymbolSH and other fonts are used.

ø	0248	can be range named
Ø	0216	can be range named
ß	0223	can be range named
µ	0181	cannot be range named

Samples row 210

Print this sample from your printer to see what works best for you:

character map	Greek C	SymbolSH
Ω	Ω	W
β	β	b
Σ	Σ	S

¼	Courier
½	Courier
¾	Courier
Δ	Century Gothic can be range named

CHARACTERS TO BE COPIED row 220

§ © ® ¶ ™ % ª ⁿ ¹ ² ³ ı 3 ¼ ⅓ ⅜ ½ ⅔ ⅛ ⅝ ¾ ⅞ ° º ± ∓ « » √ ∞ ~ ≈ ≠ ≡ ≤ ≥ ∏
α β χ ∂ δ Δ ε Є Φ κ γ Γ η φ λ Λ µ π Θ ρ σ ∑ Σ τ ς ω Ω ξ Ξ ψ Ψ ζ Ø ø ƒ ℓ € υ
← ↑ ↓ → ↔ ↕ ∫ ⌠ ⌡ █ ░ ▒ ▓ ■ □ ▪ ▫ ▬ ▲ ► ▼ ◄ ◊ ● ◦ ☼ ¶ §

Table 6-6 Characters to be copied.

To use these letters and symbols in your spreadsheet:

1 Click on one of the cells above with your cursor either hit the [F2] edit key or edit in the edit window above.

§ © ® ¶ ™ % ⁿ ¹ ² ³ ⅓ ⅔ ⅛ ⅜ ⅝ ⅞ ° º ± « » √ ∞ ~ ≈ ≠ ≡ ≤ ≥ ∑ □ ∓ ∏ □
α β χ ∂ δ Δ ε Є Φ κ γ Γ η φ λ Λ µ π Θ ρ σ ∑ Σ τ ς ω Ω ξ Ξ ψ Ψ ζ Ø ø ƒ ı ℓ € υ
← ↑ ↓ → ↔ ↕ ∫ ⌠ ⌡ █ ░ ▒ ▓ ■ □ ▪ ▫ ▬ ▲ ► ▼ ◄ ◊ ● ▪

Figure 6-7 Select the row and press [F2] edit.

2 *Paint the symbol or symbols with the* cursor and press **[Ctrl] [C]** or right click your mouse and select copy.

'§ © ® ¶ ™ % ⁿ ¹ ² ³ ⅓ ⅔ ⅛ ⅜ ⅝ ⅞ ° º ± « » √ ∞ ~ ≈ ≠ ≡ ≤ ≥ ∑ □ ∓ ∏ □

Figure 6-8 Highlight / "paint" the character with your cursor.

3 Go to the cell containing the text to be edited, highlight the spot with your cursor and press **[Ctrl] [V]** or right click and paste the symbol into the text.

Place the reinforcing 3"1/2" clear from soil row 240

'Place the reinforcing 3"|1/2" clear from soil

'Place the reinforcing 3"±|1/2" clear from soil

Place the reinforcing 3"±1/2" clear from soil

Figure 6-9 Go to your text, highlight the spot for your character, and paste.

row 250

A B C D E F G H I J K L M N O P Q R S T

GREEK CHARACTERS THAT SHOW AS RANGE NAMES

	cell range named	referencing range named cells	View these cells to see symbols as range names.
α β χ	1	1	=α_β_χ
δ Δ	2	2	=δ_Δ
ε Є Φ	3	3	=ε_Є_Φ
κ γ Γ	4	4	=κ_γ_Γ
η φ λ	5	5	=η_φ_λ
Λ π	6	6	=Λ_π
Θ ρ σ	7	7	=Θ_ρ_σ
Σ τ	8	8	=Σ_τ
ς ω Ω	9	9	=ς_ω_Ω
ξ Ξ ψ	10	10	=ξ_Ξ_ψ
Ψ ζ	11	11	=Ψ_ζ
Ø ø ƒ	12	12	=Ø_ø_ƒ
ι υ	13	13	=ι_υ
ß	14	14	=ß

Excel puts in an underscore if a space or an apostrophe is in a range name where **ε Є Φ** becomes **ε_Є_Φ**.

row 260

Table 6-10 Greek characters that serve as range names

row 270

↓→	15	15	=_↓→	™ % ^{a}	26	26	=_™_%_^{a}
←↑	16	16	=_←_↑	^{n} ı	27	26	=^{n}_ı
↔ ↕	17	17	=_↔_↕	3 ⅓	28	26	=3_⅓
∫ ⌠ ⌡	18	18	=_∫__⌠_⌡	⅜	29	26	=_⅜
█ ░ ▒	19	19	=_█_░_▒	⅔ ⅛	30	26	=_⅔_⅛
▓ ■ □	20	20	=_▓_■_□	⅝	31	26	=_⅝
▪ ▫ ▬	21	21	=_▪_▫_▬	⅞ °	32	26	=_⅞_°
▲ ►	22	22	=_▲_►	∓	33	26	=∓
▼ ◄	23	23	=_▼_◄	√ ∞	34	26	=_√_∞
◊ ● ◦	24	24	=_◊_●_◦	≈ ≠	35	26	=_≈_≠
☼	25	25	=_☼	≡ ≤ ≥	36	26	=_≡_≤_≥
				∏	37	26	=_∏

row 280

Table 6- 11 Characters that serve as range names

FORMATTING CHARACTERS USED AS RANGE NAMES

These characters come from the Arial character map and are formatted as follows:

row 290

Arial	GreekC	Courier New Greek
α β χ	α β χ	α β χ
δ	δ	δ
ε Є Φ	ε Є Φ	ε Є Φ
κ γ Γ	κ γ Γ	κ γ Γ
η φ λ	η φ λ	η φ λ
Λ π	Λ π	Λ π
Θ ρ σ	Θ ρ σ	Θ ρ σ
Σ τ	Σ τ	Σ τ
ς ω Ω	ς ω Ω	ς ω Ω
ξ Ξ ψ	ξ Ξ ψ	ξ Ξ ψ
Ψ ζ	Ψ ζ	Ψ ζ
Ø ø ƒ	Ø ø ƒ	Ø ø ƒ
ι	ι	ι
υ	υ	υ

row 300

Table 6-12 Formatting characters that serve as range names

row 310

KEYPAD ENTRY DIRECTLY INTO THE SPREADSHEET CELL

As noted above, to input a character into a spreadsheet instead of copy clipping, set **[Num Lock]** on, hold down the **[Alt]** key and input this four digit number in the right hand key pad (not the top row) to get ø. Release the **[Alt]** key to finish.

Item 1. **Unless you set Tools, Options, Transition Formula entry to on** , these values will take a range name but, when you press the **[F2]** key, the cell address is not displayed.
Also, the cell referencing the range named cell will copy as an absolutely referenced cell.

These inputs work with the menu command Edit, Find. row 320

This is not a list of all available characters.

	ascii ↓		71 G		111 o		
1 ☺	32	hidden '	72 H		112 p		
2 ●	33 !		73 I		113 q		row 330
3 ♥	34	hidden "	74 J		114 r	looks like r_	
4 ♦	35 #		75 K		115 s		
5 ♣	36 $		76 L		116 t		
6 ♠	37 %		77 M		117 u		
7 •	38 &		78 N		118 v		
8 ◘	39	hidden '	79 O		119 w		
9 ○	40 (		80 P		120 x		
10 ◙	41)		81 Q		121 y		
11 ♂	42 *		82 R	looks like R_	122 z		
12 ♀	43 +		83 S		123 {		row 340
13 ♪	44 ,		84 T		124 |		
14 ♫	45 -		85 U		125 }		
15 ☼	46 .		86 V		126 ~		
16 ►	47 command		87 W		127 ⌂		
17 ◄	48 0		88 X		128 Ç		
18 ↕	49 1		89 Y		129 ü		
19 ‼	50 2		90 Z		130 é		
20 ¶	51 3		91 [		131 â		
21 §	52 4		92		132 ä		
22 ▬	53 5		93]		133 à		row 350
23 ↨	54 6		94		134 å		
24 ↑	55 7		95 _		135 ç		
25 ↓	56 8		96 `		136 ê		
26 →	57 9		97 a		137 ë		
27 ←	58 :		98 b		138 è		
28 ∟	59 ;		99 c	looks like c_	139 ï		
29 ↔	60 <		100 d		140 î		
30 ▲	61 =		101 e		141 ì		
31 ▼	62 >		102 f		142 Ä		
	63 ?	looks like _?	103 g		143 Å		row 360
	64 @		104 h		144 É		
	65 A		105 i		145 æ		
	66 B		106 j		146 Æ		
	67 C	looks like C_	107 k		147 ô		
	68 D		108 l		148 ö		
	69 E		109 m		149 ò		
	70 F		110 n		150 û		

Table 6-13 ASCII Characters

row 370

A B C D E F G H I J K L M N O P Q R S T

KEYPAD ENTRY DIRECTLY INTO THE SPREADSHEET CELL -- Continued

151 ù	210 ╥	right side [alt] key			
152 ÿ	211 ╙	0260 .	0640 €	Ĩ	
153 Ö	212 ╘	0386 ,	0193 Á	ĩ	
154 Ü	213 ╒	0132 „	0225 á	Ī	
155 ¢	214 ╓	0133 …	0192 À	ī	
156 £	215 ╫	0134 †	0224 à	Ĭ	
157 ¥	216 ╪	0135 ‡	0194 Â	ĭ	
158 Pts	217 ┘	0136 ˆ	0226 â	Į	
159 ƒ	218 ┌	0137 ‰	0196 Ä	į	row 380
160 á	219 █	0139 ‹	0228 ä	İ	
161 í	220 ▄	0155 ›	0195 Ã	ı	
162 ó	221 ▌	0141 □ does not print	0227 ã	0205 Í	
163 ú	222 ▐	0145 ‘	0197 Å	0204 Ì	
164 ñ	223 ▀	0352 `	0229 å	0206 Î	
165 Ñ	224 α	0180 ´	Ā	0207 Ï	
166 ª	225 ß	0440 ¸	ā	Ĥ	
167 º	226 Γ	0147 “	Ă	ĥ	
168 ¿	227 π	0148 ”	ă	Ħ	
169 ⌐	228 Σ	0149 •	ą	ħ	row 390
170 ¬	229 σ	0150 –	Ą	Ĵ	
171 ½	230 µ	0351 _	0198 Æ	ĵ	
172 ¼	231 τ	0151 —	0230 æ	Ķ	
173 ¡	232 Φ	0175 ¯	Ć	ĸ	
174 «	233 Θ	0892 |	ć	Ĺ	
175 »	234 Ω	0152 ˜	Ĉ	ĺ	
176 ░	235 δ	0894 ~	ĉ	Ļ	
177 ▒	236 ∞	0153 ™	0199 Ç	ļ	
178 ▓	237 φ	0444 ¼	0231 ç	Ľ	
179 │	238 ε	0445 ½	Ċ	ľ	row 400
180 ┤	239 ∩	0446 ¾	ċ	Ŀ	
181 ╡	240 ≡	0161 ¡	Č	ŀ	
182 ╢	241 ±	0162 ¢	č	Ł	
183 ╖	242 ≥	0163 £	Ď	ł	
184 ╕	243 ≤	0164 ¤	ď	Ń	
185 ╣	244 ⌠	0165 ¥	0208 Đ	ń	
186 ║	245 ⌡	0166 ¦	đ	Ņ	
187 ╗	246 ÷	0167 §	0240 ð	ņ	
188 ╝	247 ≈	0168 ¨	0201 É	Ň	
189 ╜	248 ╨	0171 «	0233 é	ň	row 410
190 ╛	249 ·	0443 »	0200 È	ŉ	
191 ┐	250 ·	0172 ¬	0232 è	Ŋ	
192 └	251 √	0169 ©	0202 Ê	ŋ	
193 ┴	252 ⁿ	0174 ®	0234 ê	0209 Ñ	
194 ┬	253 ²	0176 °	0203 Ë	0241 ñ	
195 ├	254 ■	0177 ±	0235 ë	0442 °	
196 ─	255 hidden '	0173 -	Ę		
197 ┼	This is the end of	0215 ×	ę		
198 ╞	ascii characters ↑	0247 ÷	Ė		
199 ╟		0441 ¹	ě		row 420
200 ╚		0434 ²	0387 ƒ		
201 ╔		0179 ³	Ĝ		
202 ╩		0170 ª	ĝ		
203 ╦		0180 ´	Ğ		
204 ╠		0191 ¿	ğ		
205 ═			Ġ		
206 ╬			ġ		
207 ╧			Ģ		
208 ╨			ģ		
209 ╤					row 430

Table 6-14 ASCII Characters and Characters From The Windows Character Map.

A B C D E F G H I J K L M N O P Q R S

	Ō	0140	Œ	0223	ß
	ō	0156	œ	0222	Þ
	Ŏ		Ŕ	0254	þ
	ŏ		ŕ	0153	™
	Ő		Ŗ	0218	Ú
	ő		ŗ	0250	ú
0211	Ó		Ř	0217	Ù
0243	ó		ř	0249	ù
0210	Ò	0138	Š	0219	Û
0242	ò	0154	š	0251	û
0212	Ô		Ś	0220	Ü
0244	ô		ś	0252	ü
0214	Ö		Ŝ	0221	Ý
0246	ö		ŝ	0253	ý
0213	Õ		Ş	0159	Ÿ
0245	õ		ş	0255	ÿ
				0142	Ž
0216	Ø			0158	ž
0248	ø				Ź
	Ǿ				ź
	ǿ				Ż
	ˇ				ż
				0437	µ
				0439	·

Table 6- 14 Continued ASCII Characters and Characters From The Windows Character Map.

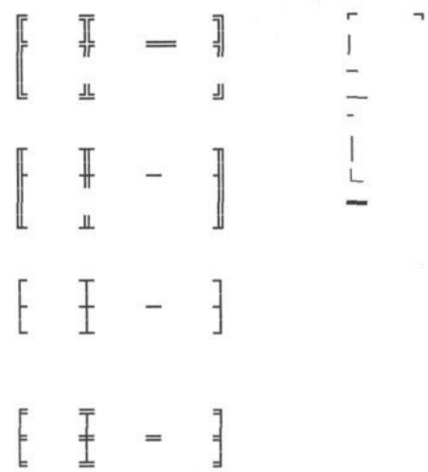


Table 6- 15 ASCII Characters used to draw figures.

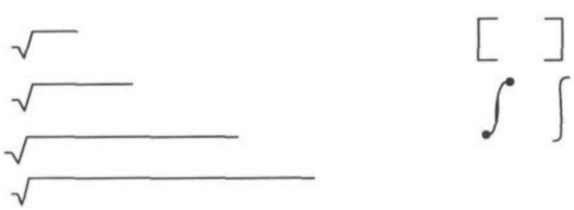
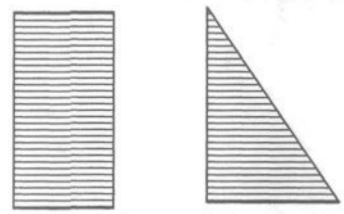


Figure 6-17 Figures that are used in formulas.

A B C D E F G H I J K L M N

GETTING STARTED

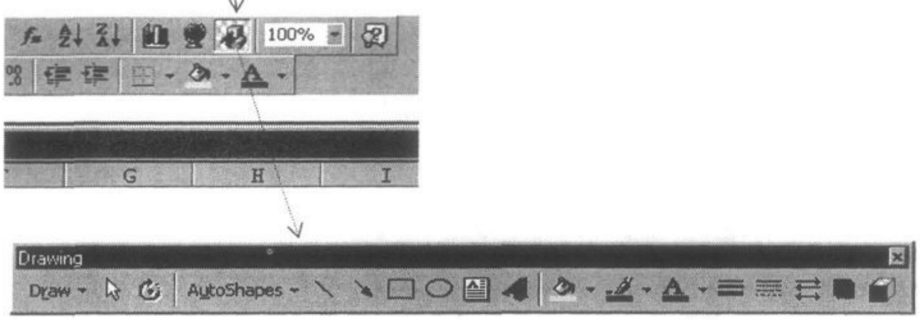
Note: for Excel to print graphics correctly on a HP LaserJet 6P
File
Print
Properties
Graphics
set to raster graphics



On our printer, the triangle will print as solid if vector graphics is selected. row 20

Figure 7-1 The File menu system to set graphics to raster graphics.

This is the Excel toolbar icon to bring up the drawing toolbar

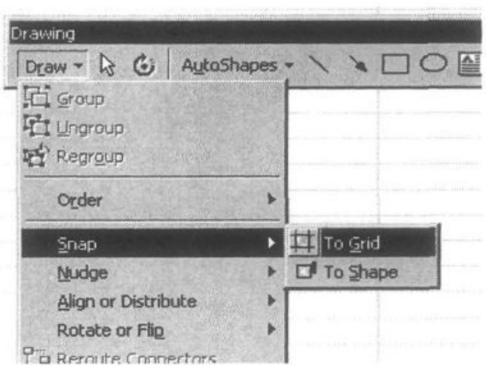


row 30

row 40

Figure 7-2 Selecting the drawing toolbar.

If you are used to drafting in AutoCAD, drawing in Excel can be a little clumsy. Here are a few tips to make drawing doable and faster.



In the drawing toolbar, select Draw and Snap. Select Snap to Grid and use the gridlines on the spreadsheet to aid in making lines meet. row 50

Draw images oversized, group, and reduce in size later. Also, zoom to 400% (which is the max zoom) to get accurate detail.

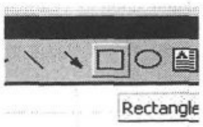
row 60

Figure 7-3 Choosing Snap-To-Grid.

row 70

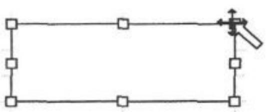
EXAMPLE -- BOX

For a quick example, we will select a box to highlight data.

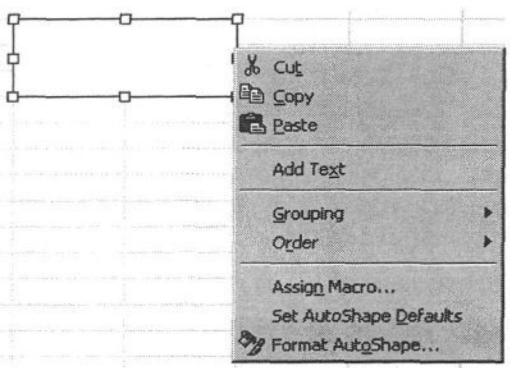


Highlight the box and left click

The box will snap to the grid. row 80



However, this box is opaque and will hide your information.

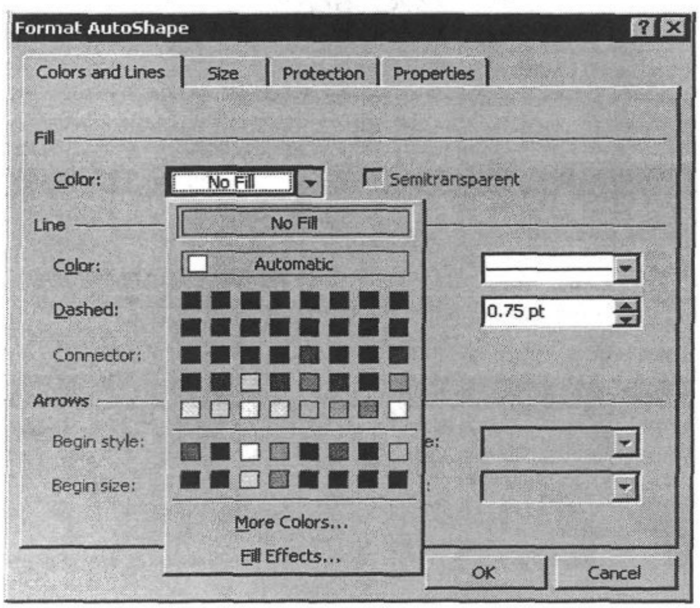


row 90

Select the box with the cursor and right click to get the drop down menu.

Left click on format shape.

row 100



Select Fill, Color, No Fill.

row 110

row 120

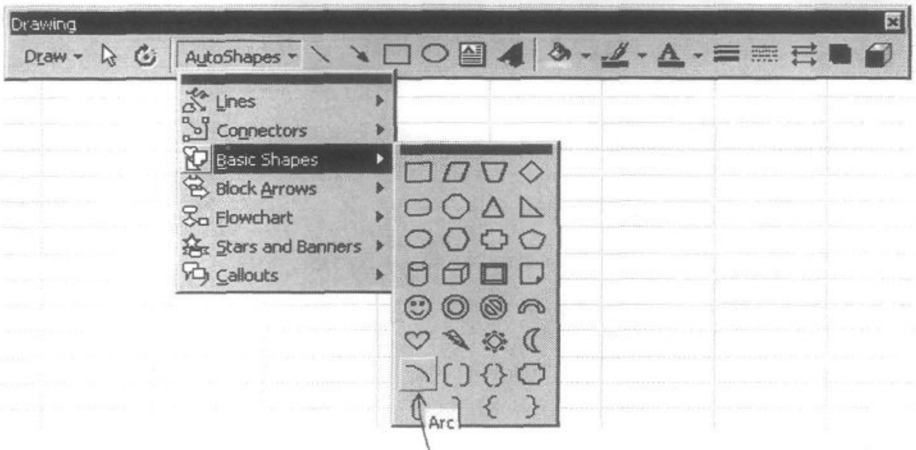
the quick brown fox ← This is the result.

Figure 7-4 Formatting a box without background.

row 130

A B C D E F G H I J K L M N

EXAMPLE -- ARC AND POINTER



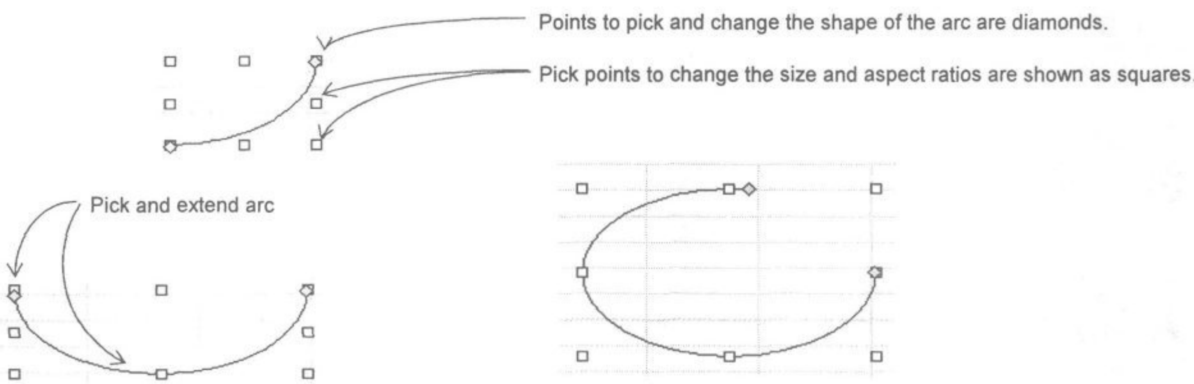
row 140

Figure 7-5 The "AutoShapes menu."

Pick AutoShapes, Basic shapes, and Arc.

row 150

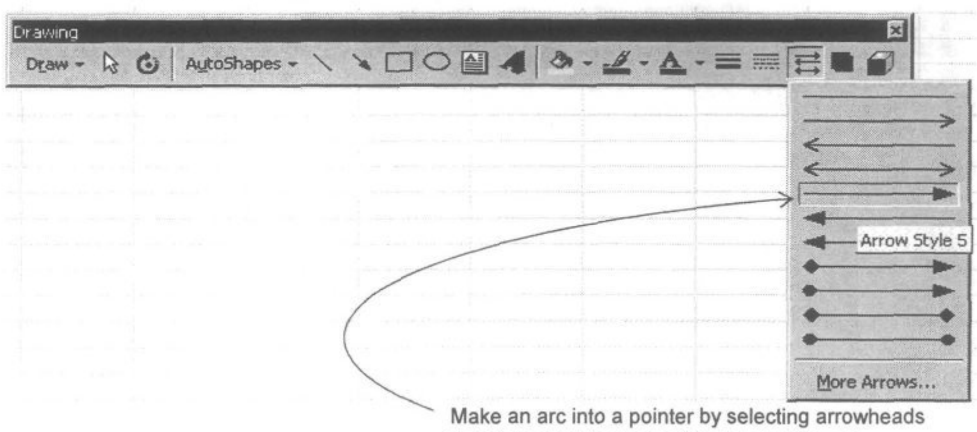
Without much explanation, here are a few ways to manipulate the arc.



row 160

Figure 7-6 Drawing an arc.

row 170



row 180

Make an arc into a pointer by selecting arrowheads
to put an arrowhead on either end of the arc.

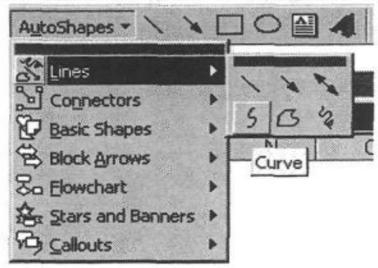
Figure 7-7 Putting an arrowhead on the arc.

row 190

A B C D E F G H I J K L M N

DRAWING LINES

Say that you want to draw a degrading sine wave.



First, in the drawing tool bar under Draw, set snap to Grid. This usually makes drawing easier.

Second, in the drawing tool bar under AutoShapes select Lines. For our purposes we will select Curve. Smash [Escape] to exit when finished with the line.

Curve works like a spline. Draw to a grid point and left click.

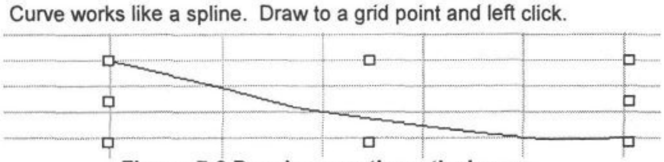


Figure 7-8 Drawing a mathematical curve.

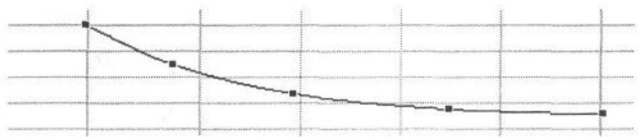


Figure 7-9 Edit Points along a line.

Edit Points allows you to move each of the nodes that you created with the left click.
Edit Points will not snap to grid.

If the line isn't correct, right click the line and click on Edit Points.

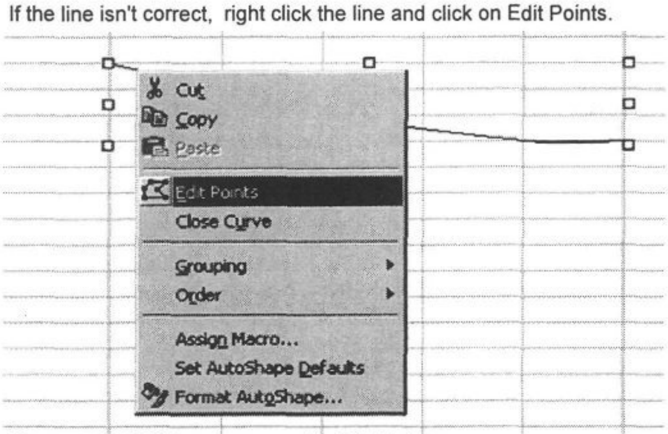


Figure 7-10 Editing a curve with Edit Points.

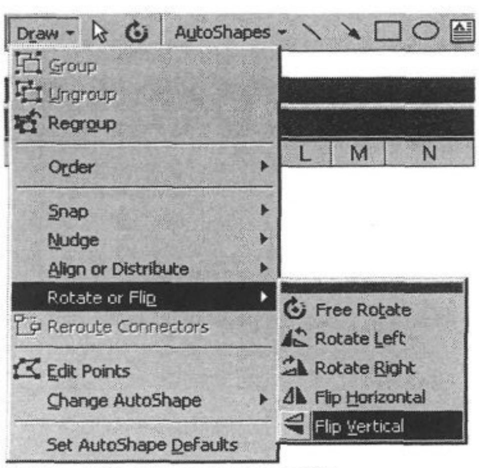


Figure 7-11 Select Rotate or Flip in the drawing toolbar.

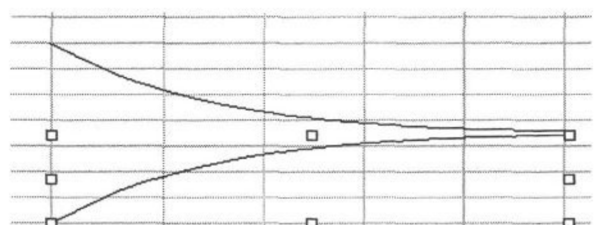


Figure 7-12 Flip a copy of the curve and then position it.

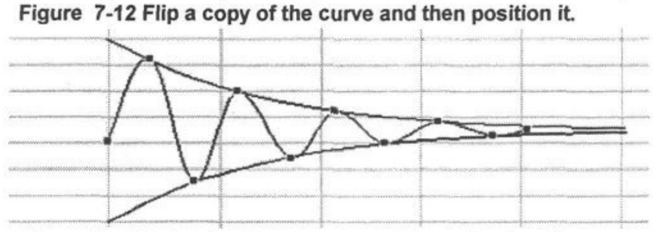
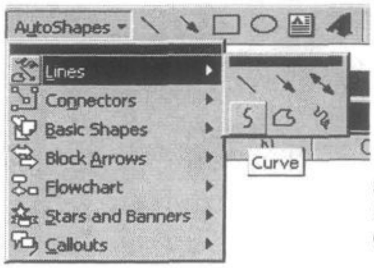


Figure 7-13 Using the Curve command from the AutoShapes Lines menu, draw in the sine wave. Here, use the Edit Points menu command to highlight the pick points used to create the wave.

row 250

A B C D E F G H I J K L M N

DRAWING LINES -- Continued



Scribble
Free Form
Curve

Figure 7-14 All three lines in the AutoShapes Lines pop-down menu will create closed line shapes which can be filled.

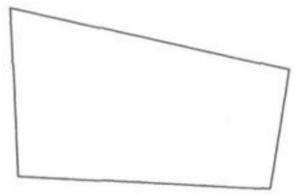


Figure 7-15 The Free Form line drawing tool.

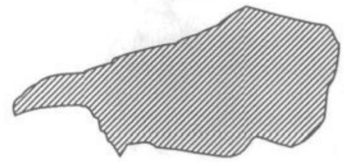


Figure 7-16 The Scribble drawing tool with a filled, closed line.

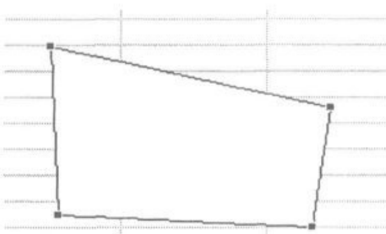


Figure 7-17 Point to this Free Form shape and right click to bring up the Edit Points menu.

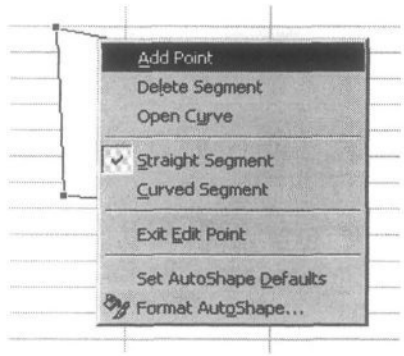


Figure 7-18 Put your cursor on a location on one of the lines and left click Add Point.

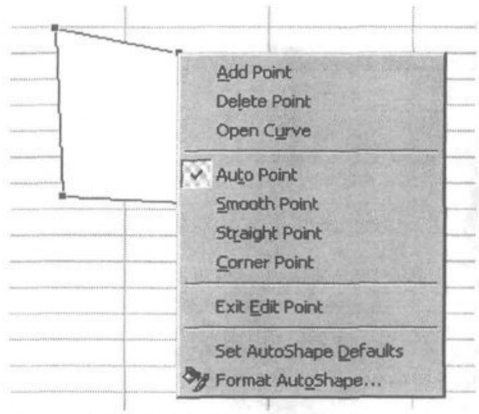


Figure 7-19 Highlight any point with your cursor, right click, and bring up the point edit menu.

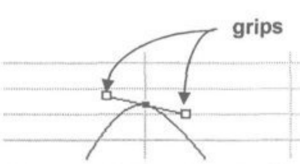


Figure 7-20 Note that the Excel Edit Points command does offer grips for closed shapes.

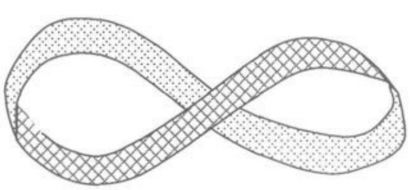


Figure 7-21 This Mobius strip was created using the Curve drawing tool and the Edit Points edit tool.

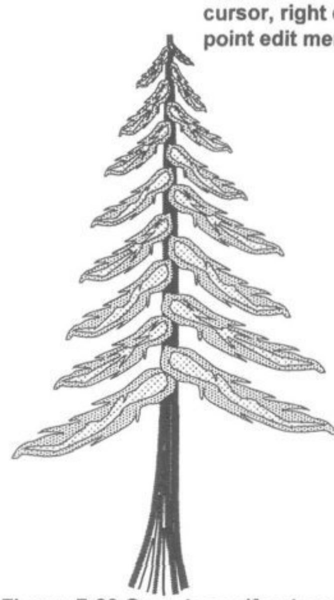


Figure 7-22 Generic conifer drawn in Excel drawing tools

row 310

A B C D E F G H I J K L M N

EXAMPLE -- DIAGRAMS

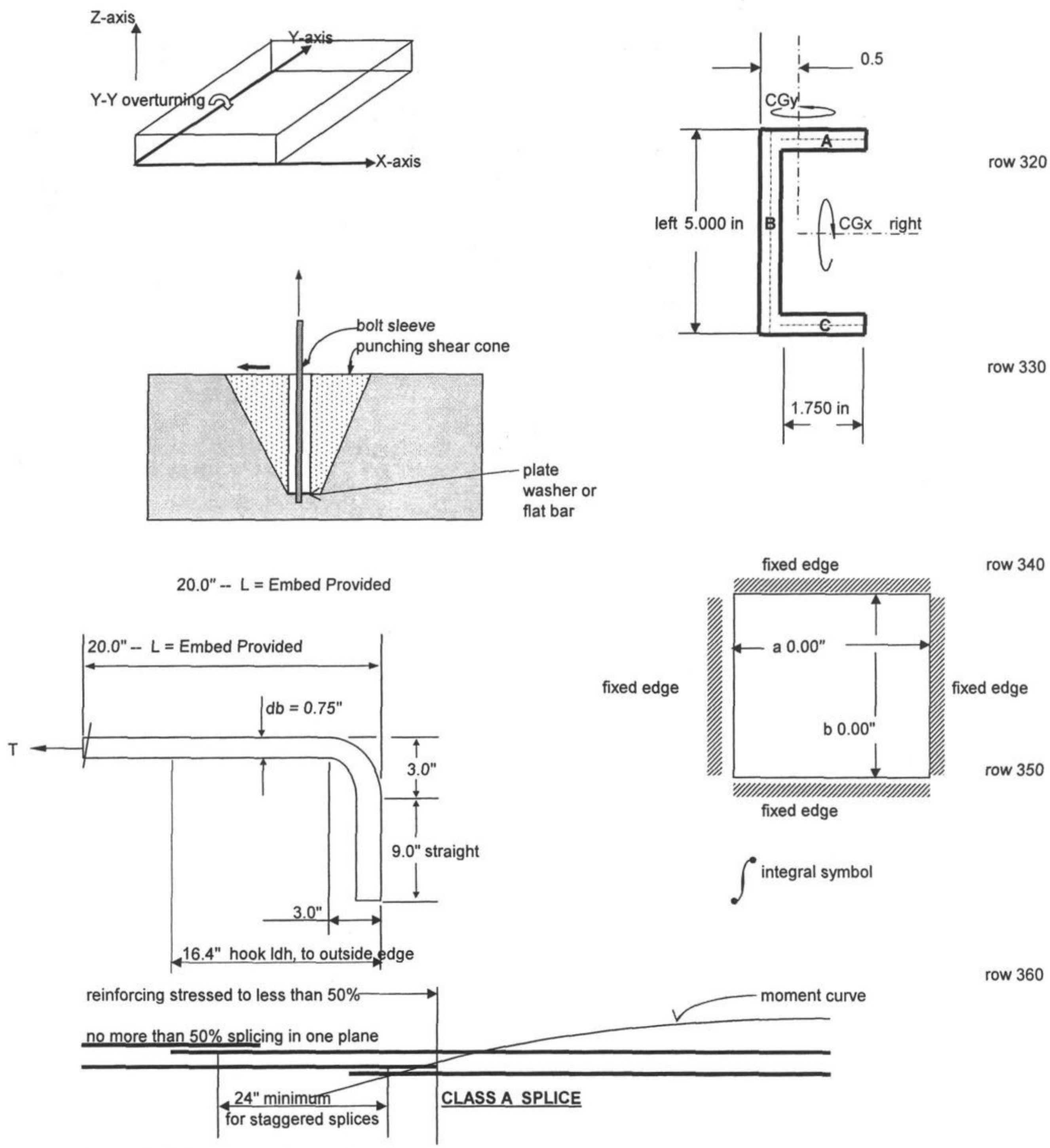


Figure 7-23 Sample drawings and symbols.

row 370

PICTURES
IMPORTING AutoCAD DRAWINGS and PICTURES

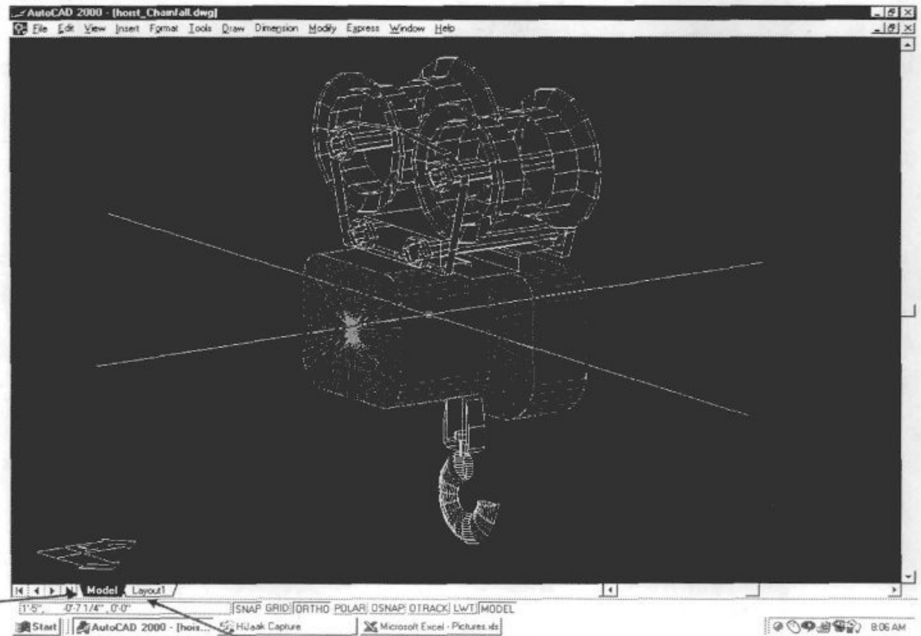
AUTOCAD DRAWINGS

This write-up is aimed at intermediate and advanced users.

There are a couple of quick ways to bring **AutoCad** drawings into **Excel**.

First -- you probably do a lot of your work in model space with a black background. But you can print out of paper space where you can xref in your title block(s) and create view ports. Set the paper space background color to white to make copy clipping an image easier. Otherwise, if you are working just in model space, you'll have to go to Tools, Options, Display, Colors, Background color, and set it to white.

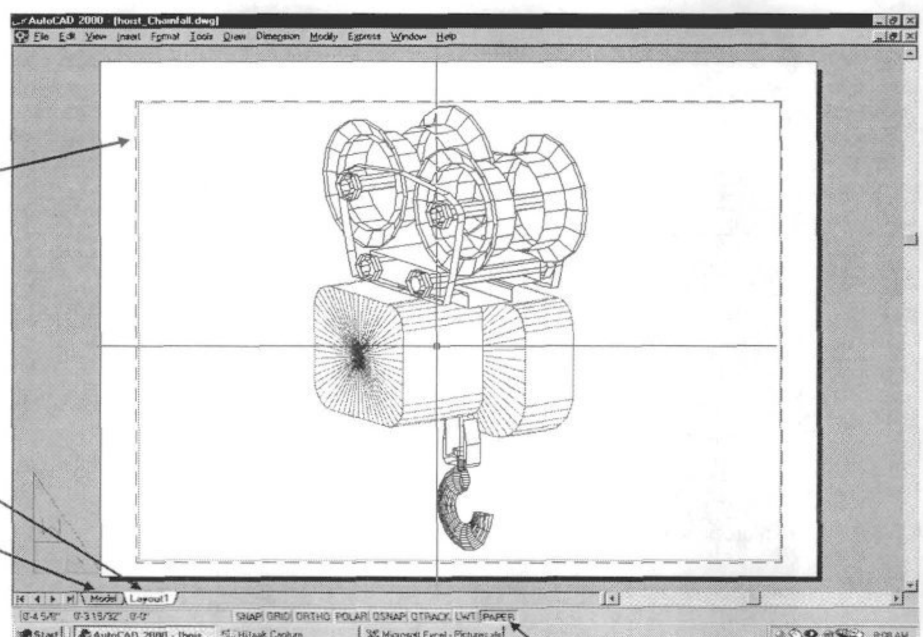
This image can be **AutoCAD 13**, **14**, or **2000**.



Model space tab indicating that this view is model space

Paper space tab

Figure 8-1 Hoist displayed in AutoCad model space.



Viewport border

Paper space tab indicating that this view is paper space layout 1

Model space tab

Figure 8-2 Hoist displayed in AutoCAD paper space.

Note that screen captures were done with **HijakkPro** and pasted into **Excel** as bit map files.

Switch into and out of model space with this tab. You can continue to draft in model space or switch into paper space for titles, notes, and etcetera.

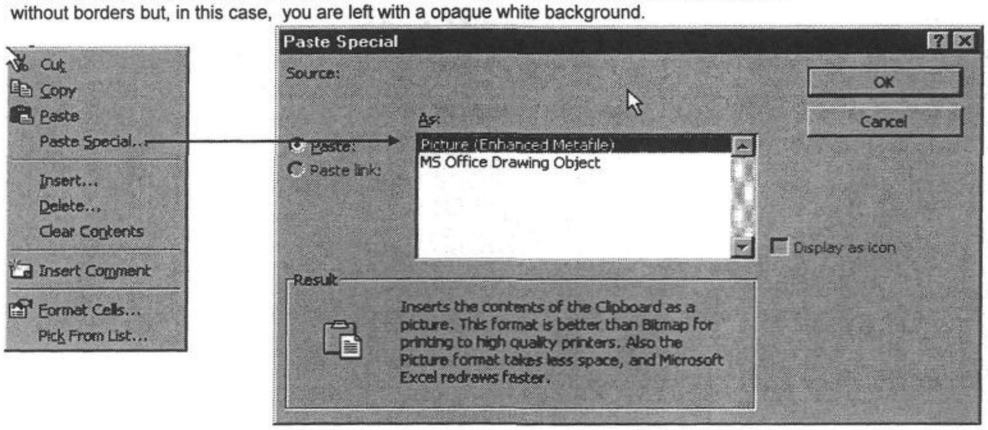
row 80

DIAGRAMS WITH BACKGROUND

Often times, simple diagrams are more easily created in AutoCad.

This **3D diagram** was created in **AutoCAD** and copy clipped with the command **[Ctrl] [c]** or **Copy** in the drop down menu (right click).

In **Excel**, use Paste Special Picture (Enhanced Metafile) This allows you to print the diagram without borders but, in this case, you are left with a opaque white background.



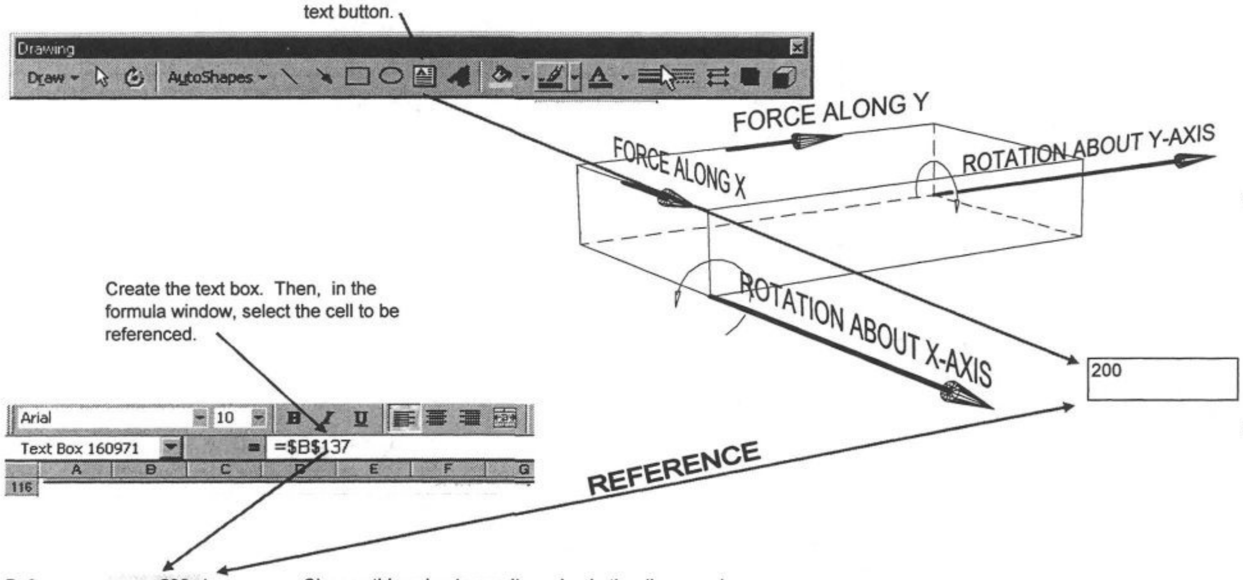
row 90

row 100

Figure 8-3 Cut-and-paste "Special."

If you want to have a dynamic diagram using numbers produced in your spreadsheet, you'll have to use the drawing tool bar and select the text button.

row 110



row 120

row 130

P_force **200** k Change this value to see the value in the diagram change.

Figure 8-4 Active text in diagrams and drawings.

row 140

If the text box is hidden, send the diagram to back with a right click of the mouse button and the appropriate choice.

row 150

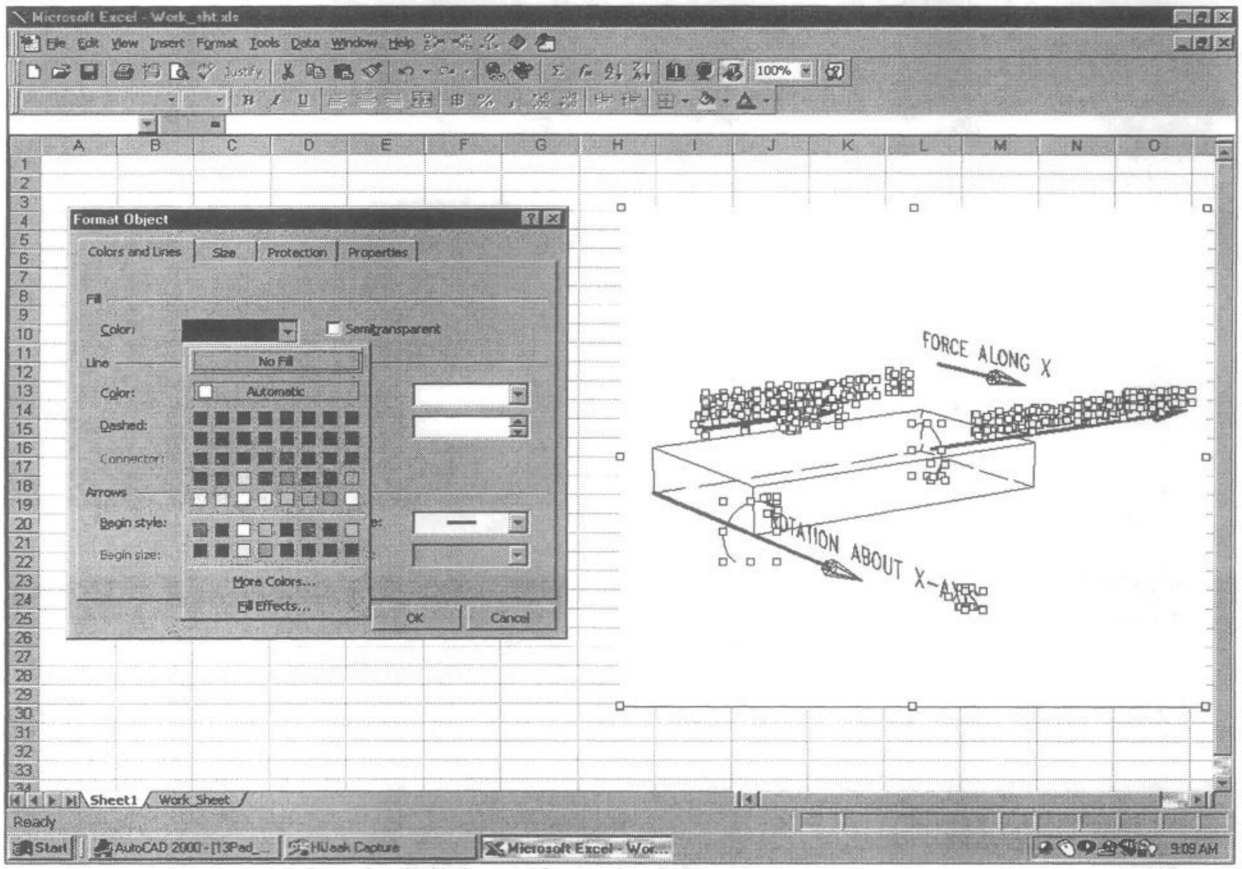
A B C D E F G H I J K L M N

DIAGRAMS WITHOUT BACKGROUND

To create a diagram without a background, copy clip out of AutoCAD and paste into the spreadsheet.

Then, click on the diagram and right click the mouse to select Grouping, Ungroup. From the same right click pop down menu select Format Object and the Colors and Lines tab.

At the Fill Color: window, click and choose No Fill.



row 160

row 170

row 180

row 190

Figure 8-5 Removing the background from an AutoCAD drawing.

Then, while holding the **[Shift]** key down, highlight an item so that the mouse pointer shows a "+." This can be a bit tricky so be forewarned. From the pop down menu select Grouping, Group to turn the diagram back into one contiguous, moveable picture. row 200

Now, values can be directly referenced in the drawing.

A complicated diagram will be harder to scroll past when you are moving around the spreadsheet. The borders will print and it cannot be edited with the Drawing tool bar.

row 210

row 220

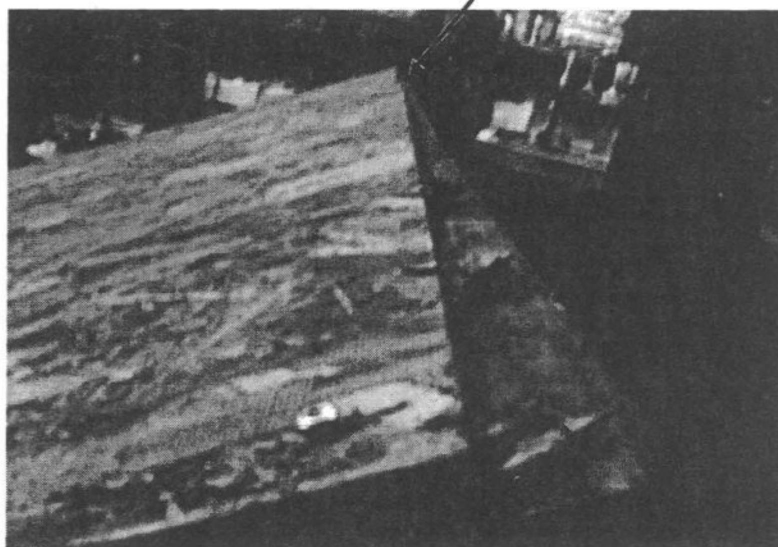
A B C D E F G H I J K L M N

PHOTOGRAPHS

Pictures can be downloaded into the spreadsheet from scanners, digital cameras, and digital and analog video tape.

This picture is downloaded from an analog video camera with **SNAPPY** by **PLAY**, Incorporated in Windows 95.

Differential slip between **OSB** panels



row 230

row 240

row 250

Gap between stud and plate

Nails torn out vertically, not horizontally as would be expected in a shear wall

Figure 8-7 An analogue cam-corder picture of the tested sample.

Also, simple diagrams can be created with the spreadsheet's drawing tools.

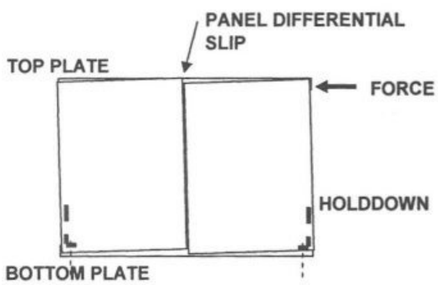


Figure 8-6 Elevation diagram of the test sample.

row 260

row 270

row 280

row 290

GRAPHING

A B C D E F G H I J K L M N

GRAPHING RECTANGLES

Generally, the **XY Scatter** graph works best for most purposes. Graphing can be used for analysis and error trapping. You'll find graphing throughout this manual.

w diagonal	**6**	in	width of inside rectangle
Horiz_1	**24**	in	length of large rectangle in the x direction
Vert_1	**24**	in	height of the large rectangle in the y direction
adjust	**3**	unitless	adjust for accuracy in convergence

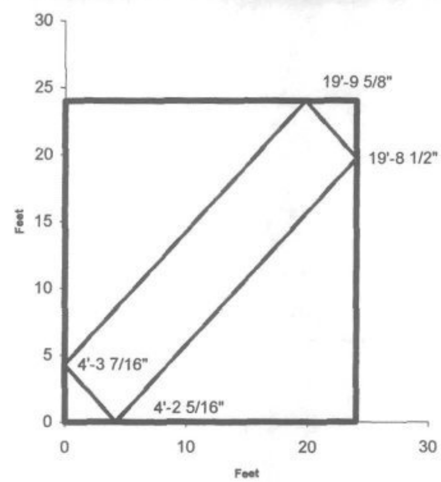


Figure 9-1 A rectangle within a rectangle.

row 30

Shooting Method

	b		vertical	difference
	4.2426	in		0.000
	4.2426	in	23.6464	-0.018
	4.1890	in	23.6509	0.002
	4.1945	in	23.6505	0.000
	4.1940	in	23.6505	0.000
	4.1940	in	23.6505	0.000
Horiz leg	4.1940	in	23.6505	0.000
Vert leg	4.2907	in	vert leg of triangle	

Highlight your graphing ranges and click on the graphing icon in the toolbar.

Graphing Ranges

x	a	b	labels
0	0		
0	24		
24	24		
24	0		
0	0		
4.1940		0.0000	4'-2 5/16"
0.0000		4.2907	4'-3 7/16"
19.8060		24.0000	19'-9 5/8"
24.0000		19.7093	19'-8 1/2"
4.1940		0.0000	
24	24		values to maintain an aspect ratio

Figure 9-2 Graph ranges.

Select XY (Scatter) and, in this case, select the icon with straight lines only.

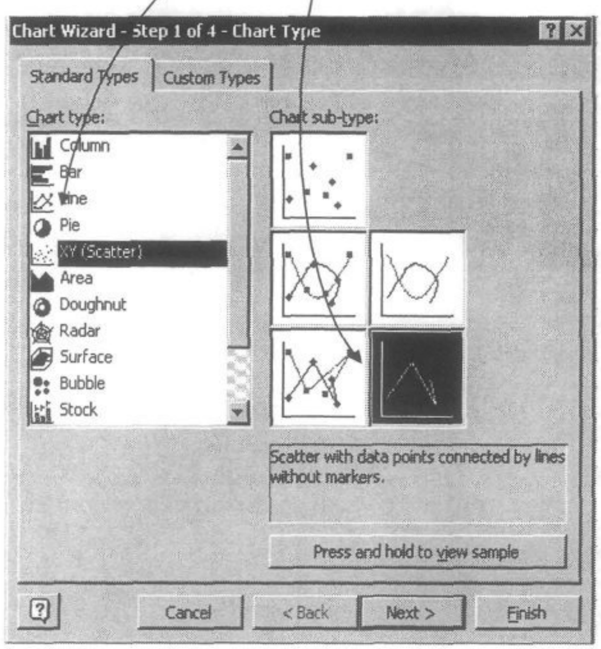


Figure 9-3 Selecting XY (Scatter) from the Chart Wizard window.

Fractions Table

0	"
0.06	1/16"
0.13	1/8"
0.19	3/16"
0.25	1/4"
0.31	5/16" row 40
0.38	3/8"
0.44	7/16"
0.5	1/2"
0.56	9/16"
0.63	5/8"
0.69	11/16"
0.75	3/4"
0.81	13/16"
0.88	7/8"
0.94	15/16"
1	1"

You can click on Next > or Finish. If you click on Next >, be sure to make sure that your data is in columns if that is how your data is arranged.

row 60

ENGINEERING with the SPREADSHEET

_9 Graphing.xls

A B C D E F G H I J K L M N

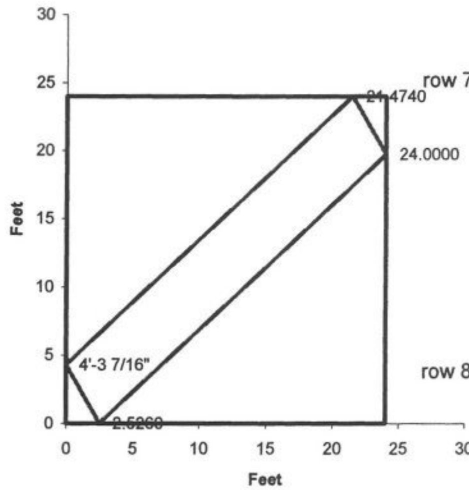
Graphing Rectangles -- Continued

w diagonal	**6**	in	width of inside rectangle
Horiz_1	**24**	in	length of large rectangle in the x direction
Vert_1	**24**	in	height of the large rectangle in the y direction
adjust	**3**	unitless	adjust for accuracy in convergence

Shooting Method

	b		vert	difference
	4.2426	in		0.000
	4.2426	in	23.6464	-0.018
	4.1890	in	23.6509	0.002
	4.1945	in	23.6505	0.000
	4.1940	in	23.6505	0.000
	4.1940	in	23.6505	0.000
Horiz leg	4.1940	in	23.6505	0.000
Vert leg	4.2907	in	vert leg of triangle	

x	a	b	labels
0	0		
0	24		
24	24		
24	0		
0	0		
2.5260		0.0000	2'-6 5/16"
0.0000		4.2907	4'-3 7/16"
21.4740		24.0000	21'-5 11/16"
24.0000		19.7093	19'-8 1/2"
2.5260		0.0000	
24	24 ←		values to maintain an aspect ratio



row 70

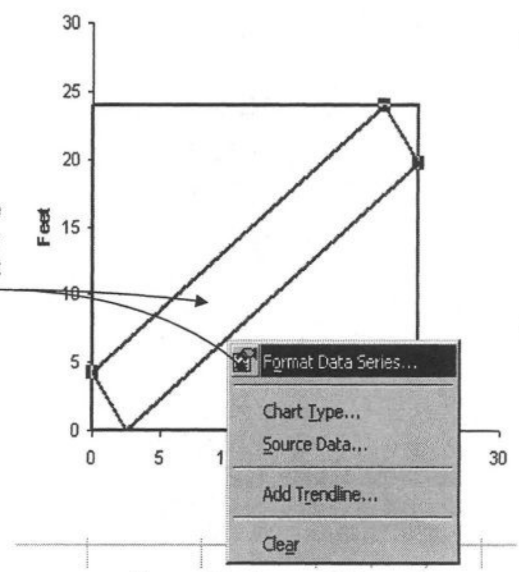
row 80

Figure 9-4 A rectangle within a rectangle.

Fractions Table

0	"
0.0625	1/16"
0.125	1/8"
0.1875	3/16"
0.25	1/4"
0.3125	5/16"
0.375	3/8"
0.4375	7/16"
0.5	1/2"
0.5625	9/16"
0.625	5/8"
0.6875	11/16"
0.75	3/4"
0.8125	13/16"
0.875	7/8"
0.9375	15/16"
1	1"

To attach labels to the rectangle, click on the shape and then select Format Data Series…



row 90

row 100

Figure 9-5 The graph formatting menu.

row 110

A B C D E F G H I J K L M N

Graphing Rectangles -- Continued

Select Data Labels and click on Show label

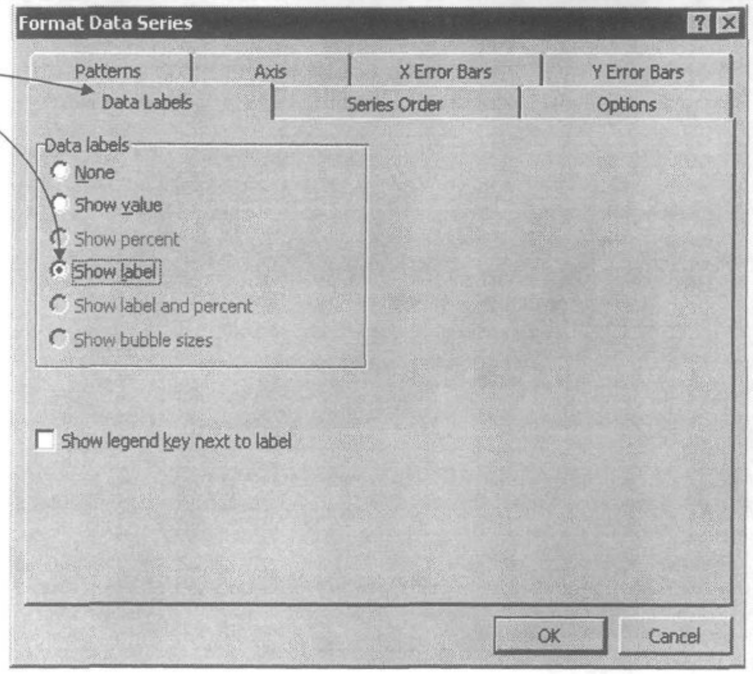
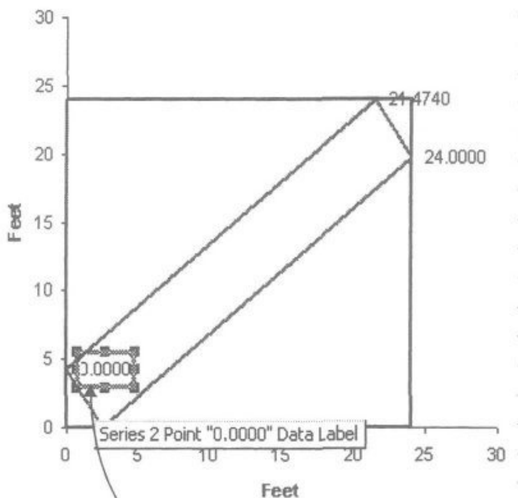


Figure 9-6 Formatting the graph.

This yields numerical labels that are attached to the points they reference.



To alter these labels to the foot and inch labels, click on the label to highlight it.

Figure 9-7 Setting up graph data labels.

Enter an equals sign "=" in the edit bar. Reference the appropriate cell to get this:

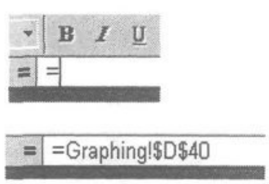


Figure 9-8 Creating the data label.

This yields a label that will follow the point it references

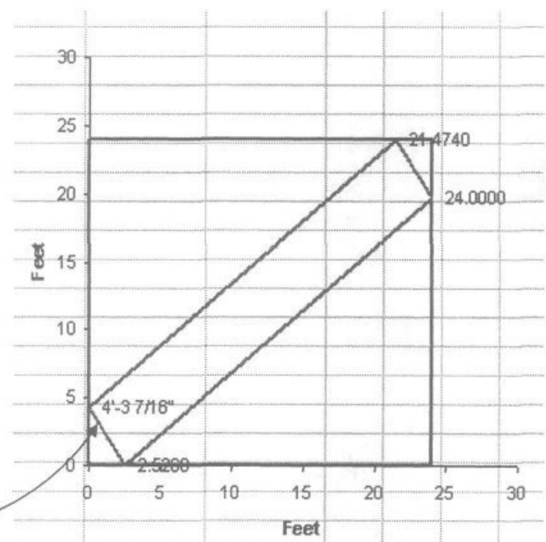


Figure 9-9 The finished data label.

Note: I did check this in AutoCAD to make sure that my math is accurate. row 160

3D ARRAY

This is a method of presenting information of a three dimensional data. In this example, Z represents individual planes. In a following example, a 3-dimensional spiral is represented where Z represents the length of the spiral.

We use an apect ratio to allow adjustment for convenient viewing.

In this case, an aspect ratio of 0, 0 allows us to superimpose the three curves.

aspect_x	**0**	unitless	*inactive input for demonstration*
aspect_y	**0**	unitless	*inactive input for demonstration*

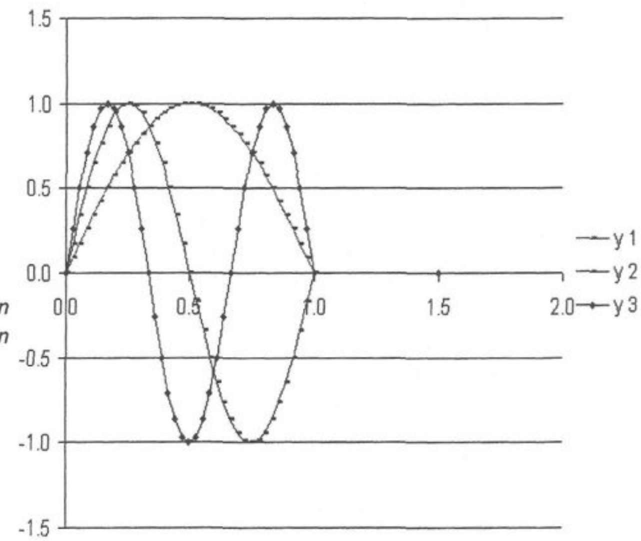


Figure 9-10 Superimposed data curves.

In this case, an aspect ration of 0.5, 0.5 is used to display the ability to show the three curves on three different planes.

aspect_x	**0.5**	unitless	*this input is active*
aspect_y	**0.5**	unitless	*this input is active*

The grid lines are part of the graphing math. They are used to help relate the three curves to each other.

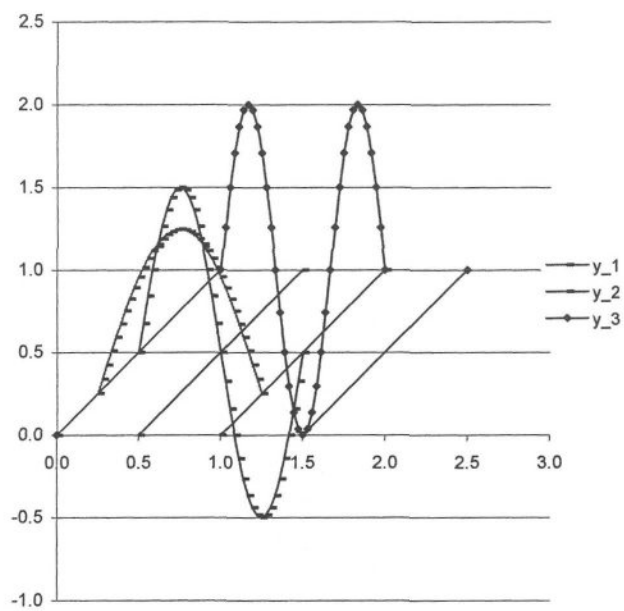


Figure 9-11 Data curves in an array.

row 210

3D ARRAY -- Continued

X 1 is an arbitrary array of numbers to plot the curves against

Z is a hard number that defines a plane

=SIN(X_1*PI())

=X_1+ Z_1*$aspect_x

=Y_1+Z_1*aspect_y

=SIN(X_1*2*PI())

=X_2+ Z_2*$aspect_x

=Y_2+Z_2*aspect_y

A	B	C	D	E	F	G	H	I	J	K	L	M	N
X_1	Y_1	Z_1	x_1	y_1	Y_2	Z_2	x_2	y_2	Y_3	Z_3	x_3	y_3	
0	0.0000	0.5	0.2500	0.2500	0.0000	1	0.5000	0.500	0.00	2	1.00	1.00	
0.0278	0.0872	0.5	0.2778	0.3372	0.1736	1	0.5278	0.674	0.26	2	1.03	1.26	
0.0556	0.1736	0.5	0.3056	0.4236	0.3420	1	0.5556	0.842	0.50	2	1.06	1.50	row 220
0.0833	0.2588	0.5	0.3333	0.5088	0.5000	1	0.5833	1.000	0.71	2	1.08	1.71	
0.1111	0.3420	0.5	0.3611	0.5920	0.6428	1	0.6111	1.143	0.87	2	1.11	1.87	
0.1389	0.4226	0.5	0.3889	0.6726	0.7660	1	0.6389	1.266	0.97	2	1.14	1.97	
0.1667	0.5000	0.5	0.4167	0.7500	0.8660	1	0.6667	1.366	1.00	2	1.17	2.00	
0.1944	0.5736	0.5	0.4444	0.8236	0.9397	1	0.6944	1.440	0.97	2	1.19	1.97	
0.2222	0.6428	0.5	0.4722	0.8928	0.9848	1	0.7222	1.485	0.87	2	1.22	1.87	
0.2500	0.7071	0.5	0.5000	0.9571	1.0000	1	0.7500	1.500	0.71	2	1.25	1.71	
0.2778	0.7660	0.5	0.5278	1.0160	0.9848	1	0.7778	1.485	0.50	2	1.28	1.50	
0.3056	0.8192	0.5	0.5556	1.0692	0.9397	1	0.8056	1.440	0.26	2	1.31	1.26	
0.3333	0.8660	0.5	0.5833	1.1160	0.8660	1	0.8333	1.366	0.00	2	1.33	1.00	row 230
0.3611	0.9063	0.5	0.6111	1.1563	0.7660	1	0.8611	1.266	-0.26	2	1.36	0.74	
0.3889	0.9397	0.5	0.6389	1.1897	0.6428	1	0.8889	1.143	-0.50	2	1.39	0.50	
0.4167	0.9659	0.5	0.6667	1.2159	0.5000	1	0.9167	1.000	-0.71	2	1.42	0.29	
0.4444	0.9848	0.5	0.6944	1.2348	0.3420	1	0.9444	0.842	-0.87	2	1.44	0.13	
0.4722	0.9962	0.5	0.7222	1.2462	0.1736	1	0.9722	0.674	-0.97	2	1.47	0.03	
0.5000	1.0000	0.5	0.7500	1.2500	0.0000	1	1.0000	0.500	-1.00	2	1.50	0.00	
0.5278	0.9962	0.5	0.7778	1.2462	-0.1736	1	1.0278	0.326	-0.97	2	1.53	0.03	
0.5556	0.9848	0.5	0.8056	1.2348	-0.3420	1	1.0556	0.158	-0.87	2	1.56	0.13	
0.5833	0.9659	0.5	0.8333	1.2159	-0.5000	1	1.0833	0.000	-0.71	2	1.58	0.29	
0.6111	0.9397	0.5	0.8611	1.1897	-0.6428	1	1.1111	-0.143	-0.50	2	1.61	0.50	row 240
0.6389	0.9063	0.5	0.8889	1.1563	-0.7660	1	1.1389	-0.266	-0.26	2	1.64	0.74	
0.6667	0.8660	0.5	0.9167	1.1160	-0.8660	1	1.1667	-0.366	0.00	2	1.67	1.00	
0.6944	0.8192	0.5	0.9444	1.0692	-0.9397	1	1.1944	-0.440	0.26	2	1.69	1.26	
0.7222	0.7660	0.5	0.9722	1.0160	-0.9848	1	1.2222	-0.485	0.50	2	1.72	1.50	
0.7500	0.7071	0.5	1.0000	0.9571	-1.0000	1	1.2500	-0.500	0.71	2	1.75	1.71	
0.7778	0.6428	0.5	1.0278	0.8928	-0.9848	1	1.2778	-0.485	0.87	2	1.78	1.87	
0.8056	0.5736	0.5	1.0556	0.8236	-0.9397	1	1.3056	-0.440	0.97	2	1.81	1.97	
0.8333	0.5000	0.5	1.0833	0.7500	-0.8660	1	1.3333	-0.366	1.00	2	1.83	2.00	
0.8611	0.4226	0.5	1.1111	0.6726	-0.7660	1	1.3611	-0.266	0.97	2	1.86	1.97	
0.8889	0.3420	0.5	1.1389	0.5920	-0.6428	1	1.3889	-0.143	0.87	2	1.89	1.87	row 250
0.9167	0.2588	0.5	1.1667	0.5088	-0.5000	1	1.4167	0.000	0.71	2	1.92	1.71	
0.9444	0.1736	0.5	1.1944	0.4236	-0.3420	1	1.4444	0.158	0.50	2	1.94	1.50	
0.9722	0.0872	0.5	1.2222	0.3372	-0.1736	1	1.4722	0.326	0.26	2	1.97	1.26	
1.0000	0.0000	0.5	1.2500	0.2500	0.0000	1	1.5000	0.500	0.00	2	2.00	1.00	
max x grid	1.0000												
max y grid	1.0000		0	0			0	0			0	0	
			0.2500	0.2500			0.5000	0.5000			1.00	1.00	
			0.5000	0			1	0			1.5	0	
			1.5000	1.0000			2.0000	1.0000			2.50	1.00	row 260

A B C D E F G H I J K L M N

3D SPIRAL

This example graphs three bolt threads in 3D.

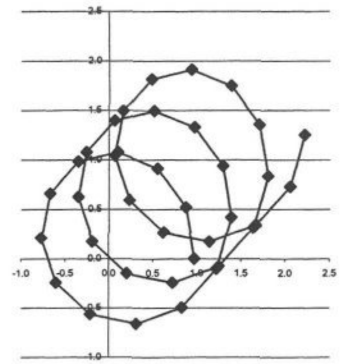


Figure 9-12 A 3D spiral.

aspect_x 5 unitless
aspect_y 5 unitless

D_threads 0.9729 in

Hard Number series — =(SIN(Number/6*PI())) — =(COS(Number/6*PI())) — $D_threads * Cosine — $D_threads * Sine — Number series — =X + Z*$a — =Z + Z*$a

	Sine	Cosine	X	Y	Z	x	y	
0	0.0000	1.0000	0.9729	0.0000	0.0000	0.9729	0.0000	
1	0.5000	0.8660	0.8426	0.4865	0.0069	0.8773	0.5212	
2	0.8660	0.5000	0.4865	0.8426	0.0139	0.5559	0.9120	
3	1.0000	0.0000	0.0000	0.9729	0.0208	0.1042	1.0771	
4	0.8660	-0.5000	-0.4865	0.8426	0.0278	-0.3476	0.9815	
5	0.5000	-0.8660	-0.8426	0.4865	0.0347	-0.6690	0.6601	
6	0.0000	-1.0000	-0.9729	0.0000	0.0417	-0.7646	0.2083	
7	-0.5000	-0.8660	-0.8426	-0.4865	0.0486	-0.5995	-0.2434	row 280
8	-0.8660	-0.5000	-0.4865	-0.8426	0.0556	-0.2087	-0.5648	
9	-1.0000	0.0000	0.0000	-0.9729	0.0625	0.3125	-0.6604	
10	-0.8660	0.5000	0.4865	-0.8426	0.0694	0.8337	-0.4954	
11	-0.5000	0.8660	0.8426	-0.4865	0.0764	1.2245	-0.1045	
12	0.0000	1.0000	0.9729	0.0000	0.0833	1.3896	0.4167	
13	0.5000	0.8660	0.8426	0.4865	0.0903	1.2940	0.9379	
14	0.8660	0.5000	0.4865	0.8426	0.0972	0.9726	1.3287	
15	1.0000	0.0000	0.0000	0.9729	0.1042	0.5208	1.4938	
16	0.8660	-0.5000	-0.4865	0.8426	0.1111	0.0691	1.3981	
17	0.5000	-0.8660	-0.8426	0.4865	0.1181	-0.2523	1.0767	row 290
18	0.0000	-1.0000	-0.9729	0.0000	0.1250	-0.3479	0.6250	
19	-0.5000	-0.8660	-0.8426	-0.4865	0.1319	-0.1829	0.1733	
20	-0.8660	-0.5000	-0.4865	-0.8426	0.1389	0.2080	-0.1481	
21	-1.0000	0.0000	0.0000	-0.9729	0.1458	0.7292	-0.2438	
22	-0.8660	0.5000	0.4865	-0.8426	0.1528	1.2504	-0.0787	
23	-0.5000	0.8660	0.8426	-0.4865	0.1597	1.6412	0.3121	
24	0.0000	1.0000	0.9729	0.0000	0.1667	1.8063	0.8333	
25	0.5000	0.8660	0.8426	0.4865	0.1736	1.7106	1.3545	
26	0.8660	0.5000	0.4865	0.8426	0.1806	1.3892	1.7454	
27	1.0000	0.0000	0.0000	0.9729	0.1875	0.9375	1.9104	row 300
28	0.8660	-0.5000	-0.4865	0.8426	0.1944	0.4858	1.8148	
29	0.5000	-0.8660	-0.8426	0.4865	0.2014	0.1644	1.4934	
30	0.0000	-1.0000	-0.9729	0.0000	0.2083	0.0687	1.0417	
31	-0.5000	-0.8660	-0.8426	-0.4865	0.2153	0.2338	0.5899	
32	-0.8660	-0.5000	-0.4865	-0.8426	0.2222	0.6246	0.2685	
33	-1.0000	0.0000	0.0000	-0.9729	0.2292	1.1458	0.1729	
34	-0.8660	0.5000	0.4865	-0.8426	0.2361	1.6670	0.3380	
35	-0.5000	0.8660	0.8426	-0.4865	0.2431	2.0579	0.7288	
36	0.0000	1.0000	0.9729	0.0000	0.2500	2.2229	1.2500	

row 310

A B C D E F G H I J K L M N

3D BOX -- SIMPLE PROJECTION

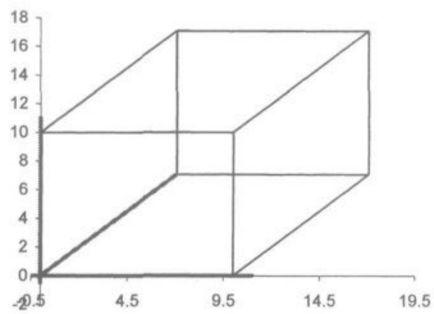
Vpoint	**45**	degrees
	0.785	rad
x	**0.70711**	
y	**0.70711**	
L_X	**10**	
L_Y	**10**	
L_Z	**10**	depth

This is just one method of showing 3D data in a 2D graph. The image of a box is fairly easy to manipulate. Notice that the X, Y, and Z axis are displayed in a different color. Gridlines could be shown in a third color with lines formatted to be much thinner than the box outline.

The box can be replaced with another figure or data points. Separate data groups are separated by a blank row.

row 320

	x	y	z
x axis	-0.5		0
	11		0
y axis	0		-0.5
	0		11
z axis	0		0
	7.0710678		7.071067812
	0	0	
	10	0	
	10	10	
	0	10	
	0	0	
	7.0710678	7.0710678	
	17.071068	7.0710678	
	17.071068	17.071068	
	7.0710678	17.071068	
	7.0710678	7.0710678	
	0	0	
	0	7.0710678	
	10	0	
	17.071068	7.0710678	
	10	10	
	17.071068	17.071068	
	0	10	
	7.0710678	17.071068	



row 330

Figure 9-13 Set the aspect ratio for this 3D box in Lx, Ly, and Lz above.

row 340

row 350

row 360

A B C D E F G H I J K L M N

3D BOX -- ORTHOGRAPHIC PROJECTION

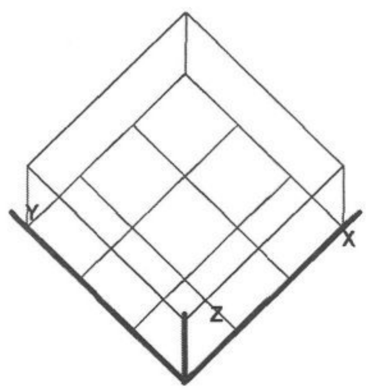
This is another method of showing **3D** *data in a* **2D** *graph. The inputs are the same as* **AutoCAD** *inputs and* the results are similar to **AutoCAD** views. The Z-axis is always vertical.

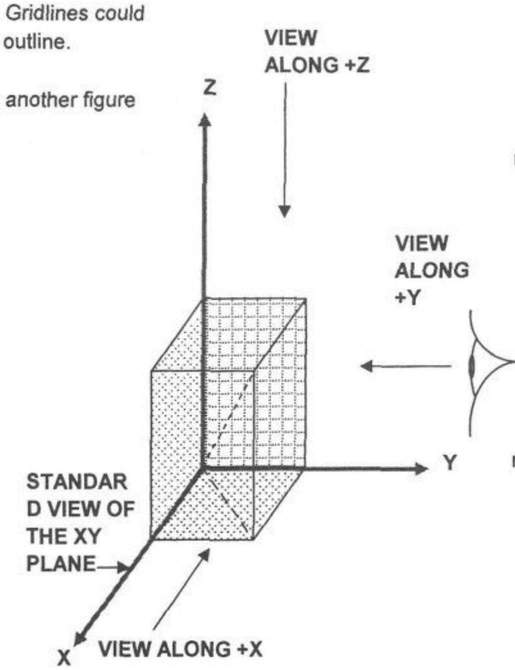
Notice that in the Excel the **X**, **Y**, *and* **Z** *axis are displayed in a different color. Gridlines could* be shown in a third color with lines formatted to be much thinner than the box outline.

The image of a box is fairly easy to manipulate. The box can be replaced with another figure or data plots. Separate data groups are separated by a blank row.

row 370

	VPoint
VPx	-0.2
VPy	-0.2
VPz	1
L_X	10
L_Y	10
L_Z	10





row 380

Figure 9-14 The diagram of ACAD type orthographic views.

Conditional formating to highlight logic choice

row 390

Figure 9-15 Graph of an orthographic box.

Logic Table

	1, 1, 1	0, 1, 1	1, 0, 0	1, 1, 0	0, 1, 0	1, 0, 1	-1,-1,0	-1,-1,1	-1,0,-	-1,0,-	-1,-1,-1	
logic	0	0	0	0	0	0	0	1	0	0	0	0
VPx mult x	-1	-1	1	-1	-1	1	1	1	1	1	1	-1
VPx mult y	-1	1	-1	1	1	-1	1	1	-1	1	-1	1
VPy mult x	1	-1	1	1	1	1	-1	-1	1	1	-1	-1
VPy mult y	-1	-1	1	1	1	1	1	1	1	-1	-1	-1
VPx mult x	0	0	0	0	0	0	0	1	0	0	0	0
VPx mult y	0	0	0	0	0	0	0	1	0	0	0	0
VPy mult x	0	0	0	0	0	0	0	-1	0	0	0	0
VPy mult y	0	0	0	0	0	0	0	1	0	0	0	0

logic results		
x	1	
y		1
x	-1	
y		1

row 410

GRAPHING

3D BOX -- ORTHOGRAPHIC PROJECTION -- Continued

A	B	C	D	E	F	G	H	I	N
0, 0, 0	0, 0, -1	1, 0, 0					**Reference**		
0	0	0					Radians	Degrees	
1	-1	0					0.524	30	
0	0	0					0.785	45	
0	0	-1					1.047	60	
1	1	0					1.571	90	
			logic results				3.142	180	
0	0	0	**0**						
0	0	0	**0**						row 420
0	0	0	**0**						
0	0	0	**0**						
	0.276		calculations	x	y	output to graph		y	
VPx	0.272		x axis	0.70711	0.68041	x axis	**0.70711**	**0.6804**	
VPy	0.272		y axis	0.70711	0.68041	y axis	**-0.7071**	**0.6804**	
VPz	0.283		z axis	0	0.27217	z axis	**0**	**0.2722**	

X, Y, and Z axis

A	B	C	D	F	G	H	N
multiplier	**1.1**						row 430
max	10						
max mult	11			Note that the graph makes use of two X-axis to conserve space in the template (and printout).			
	x	y	y 2		x	y	
x axis	0		0	along x	-2.357	2.268	
	7.77819		7.48454		4.71406	9.07218	
y axis	0		0		-4.7141	4.5361	
	-7.77819		7.48454		2.35703	11.34	
							row 440
z axis	0		0	along y	2.35703	2.268	
	0		2.99382		-4.71406	9.07218	
standoff	-0.8556		-0.8233		4.71406	4.5361	
					-2.35703	11.3402	
	0.8556		-0.3293				
					7.07109	6.8041	
top plane	**0**	**0**			7.07109	9.5258	
	7.0710855	**6.8041316**					
	0	**13.60826**			0	13.608	row 450
	-7.0710855	**6.8041316**			0	16.33	
	0	**0**					
					-7.0711	6.8041	
bottom plane	0	2.7216527			-7.0711	9.5258	
	7.0710855	9.5257844					
	0	16.329916					
	-7.0710855	9.5257844					
	0	2.7216527					
							row 460

PART 2:

APPLICATION BASICS

CONSULTING COMPANY

NOTES

ENGINEERING with the SPREADSHEET

A B C D E F G H I J K L M N

20

30

40

50

60

ABSOLUTE and RELATIVE REFERENCES

OVERVIEW

Absolute and relative cell referencing are important when copying equations.

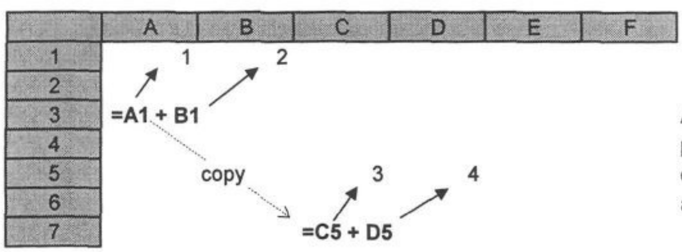
A relative reference is not a permanent reference to a particular cell. If a relatively referenced equation is copied to another position, the cell(s) it refers to will change.

An absolute reference is a permanent reference to a particular cell. When the absolutely referenced equation is copied to another position, it will still refer to the same cell(s).

Absolute and relative references may be mixed, as can be seen in the examples below.

You can input the **$** by hand or press the **[F4]** key while in edit mode.
Pressing the **[F4]** key two or three times will cycle the reference through:

absolute column and row	=$A$14
relative column and absolute row	=A$14
absolute column and relative row	=$A14
relative column and relative row	=A14



A relative reference is not a permanent reference to a particular cell. If a relatively referenced equation is copied to another position, it will refer to a new cell address.

This is useful in creating look-up tables and in numerical integration.

Figure 10-1 RELATIVE REFERENCING

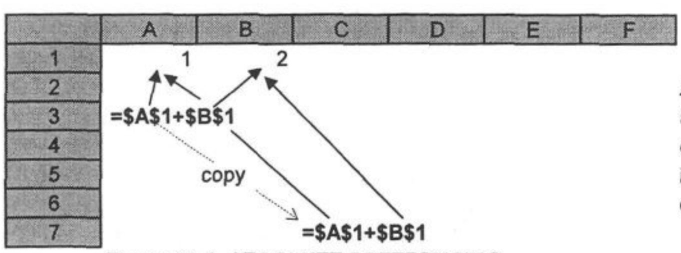


Figure 10-2 ABSOLUTE REFERENCING

An absolute reference is a permanent reference to a particular cell. When the absolutely referenced equation is copied to another position, it will still refer to the same **$A $1+$B$1** cell(s).

Samples of Referencing

=**B$3+B4**
=SUM(**$B$5:$D$7, B8**) where **B5** through **D7** is a rectangular range of cells

ABSOLUTE and RELATIVE REFERENCES

A B C D E F G H I J K L M N

OVERVIEW -- Continued

The Sample Matrix

Relative reference back to **A**.

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

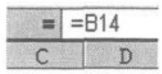


Figure 10-3 Look at the formula bar.

Then copy this cell to the rest of the matrix

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

This is what the above matrix looks like with all of the cells "parked."

=A63	=B63	=C63	=D63
=A64	=B64	=C64	=D64
=A65	=B65	=C65	=D65
=A66	=B66	=C66	=D66

Figure 10-4 Relative Column / Relative Row Array

Here, the **row** is absolutely referenced and the **columns** are relatively referenced.

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

row 70

A	B	C	D
A	B	C	D
A	B	C	D
A	B	C	D

This is what the matrix looks like with all of the cells "parked."

=I$63	=J$63	=K$63	=L$63
=I$63	=J$63	=K$63	=L$63
=I$63	=J$63	=K$63	=L$63
=I$63	=J$63	=K$63	=L$63

row 80

Figure 10-5 Relative Column / Absolute Row Array

Here, the **row** is relatively referenced and the **columns** are absolutely referenced.

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

A	A	A	A
E	E	E	E
I	I	I	I
M	M	M	M

And with the cells parked.

=$A86	=$A86	=$A86	=$A86
=$A87	=$A87	=$A87	=$A87
=$A88	=$A88	=$A88	=$A88
=$A89	=$A89	=$A89	=$A89

Figure 10-6 Relative Column / Relative Row Array

Row and **column** for the cell containing **A** are absolutely referenced.

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

row 90

A	A	A	A
A	A	A	A
A	A	A	A
A	A	A	A

And with the cells parked.

row 100

=$I$86	=$I$86	=$I$86	=$I$86
=$I$86	=$I$86	=$I$86	=$I$86
=$I$86	=$I$86	=$I$86	=$I$86
=$I$86	=$I$86	=$I$86	=$I$86

Figure 10-7 Absolute Column / Absolute Row Array

park — put an apostrophe or hit the spacebar in front of the equals "=" sign to park the equation

row 110

ABSOLUTE and RELATIVE REFERENCES

A	B	C	D	E	F	G	H	I	J	K	L	M	N

MOVING AN ENTIRE MODULE THAT INCLUDES ABSOLUTE REFERENCES

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

A is absolutely referenced in this array

A	A	A	A
A	A	A	A
A	A	A	A
A	A	A	A

=$A$112	=$A$112	=$A$112	=$A$112
=$A$112	=$A$112	=$A$112	=$A$112
=$A$112	=$A$112	=$A$112	=$A$112
=$A$112	=$A$112	=$A$112	=$A$112

Figure 10-8 Absolute Column / Absolute Row Array

A				
E	B	C	D	
I	F	G	H	
M	J	K	L	
	N	O	P	

Move the absolutely referenced cell containing **A** and the array will still reference the relocated cell.

A	A	A	A	
A	A	A	A	row 120
A	A	A	A	
A	A	A	A	

=$H$112	=$H$112	=$H$11:	=$H$112
=$H$112	=$H$112	=$H$11:	=$H$112
=$H$112	=$H$112	=$H$11:	=$H$112
=$H$112	=$H$112	=$H$11:	=$H$112

Figure 10-9 Relocated Input

But try to copy the entire array.

A	B	C	D	row 130
E	F	G	H	
I	J	K	L	
M	N	O	P	

A is absolutely referenced in this array

A	A	A	A	
A	A	A	A	
A	A	A	A	
A	A	A	A	row 140

And this is what you get. The referenced cell is still cell **A112**.

=$A$112	=$A$112	=$A$112	=$A$112
=$A$112	=$A$112	=$A$112	=$A$112
=$A$112	=$A$112	=$A$112	=$A$112
=$A$112	=$A$112	=$A$112	=$A$112

Figure 10-10 The copied array.

Note:
If you copy this array to another spreadsheet, the array will refer back to cell A112 in the new spreadsheet. Ir *this way you create a link between two* spreadsheets. You may not want to have done this.

COPYING AN ENTIRE MODULE THAT INCLUDES ABSOLUTE REFERENCES

A. **SAVE THE TEMPLATE THAT YOU ARE GOING TO COPY FROM.**
This is to prevent a disaster.

DO NOT SAVE THE SPREADSHEET AFTER THE NEXT STEP.

B. Remove all range names. Otherwise, you will have unwanted references to the spreadsheet you are copying from.

A	B	C	D	row 150
E	F	G	H	
I	J	K	L	
M	N	O	P	
A	A	A	A	
A	A	A	A	
A	A	A	A	
A	A	A	A	

Figure 10-11 An array to be copied.

row 160

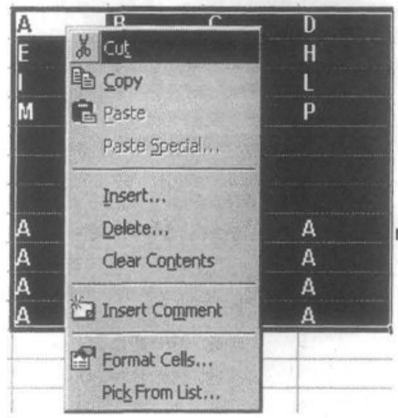
A B C D E F G H I J K L M N

COPYING AN ENTIRE MODULE THAT INCLUDES ABSOLUTE REFERENCES -- Continued

C. Highlight the array or module to be copied to another spreadsheet and invoke the **Cut** command.

Position your cursor in the other template and press **Copy** (**[Ctrl] [V]**). You will have copied the entire array (module) with all references and absolute references intact.

D. Make sure that transition formula evaluation and Transition formula entry are checked in the Tools, Options menu or some functions will not calculate correctly.

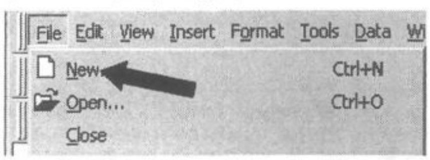


row 170

ALTERNATIVE: COPY AN ARRAY OR MODULE BACK INTO THE SAME TEMPLATE

Figure 10-12 Cut the array.

A. Open a new (temporary) spreadsheet.



row 180

Figure 10-13 The control panel.

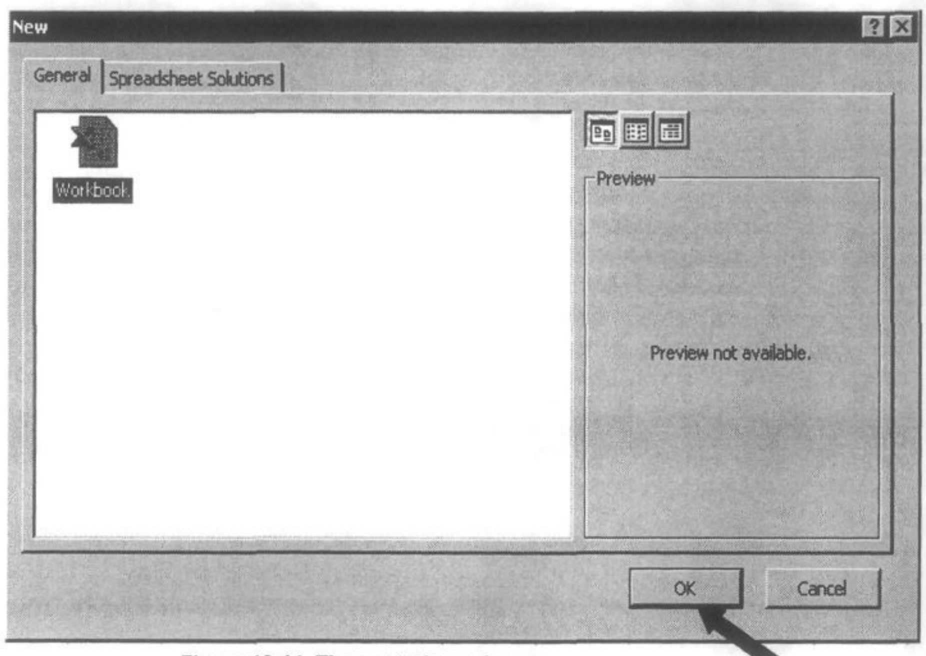


Figure 10-14 The control panel menu.

Press OK and bring up the new spreadsheet.

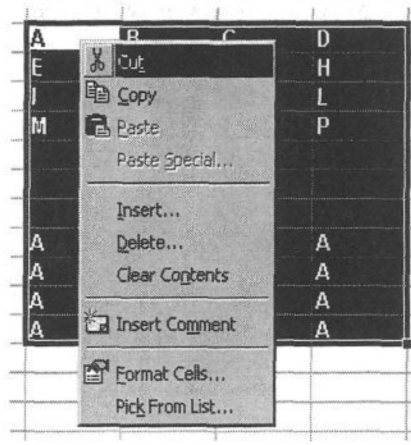
row 210

ABSOLUTE and RELATIVE REFERENCES

A B C D E F G H I J K L M N

ALTERNATIVE: COPY AN ARRAY OR MODULE BACK INTO THE SAME TEMPLATE -- Continued

B. Highlight and **Cut** the array.



ow 220

C. Reopen your current spreadsheet and press "Yes" when Excel asks you if you really want to reopen this file discard the changes in you made. *Press "No" and you have made an error that the backup button can't fix.*

Figure 10-15 A pop-down menu.

row 230

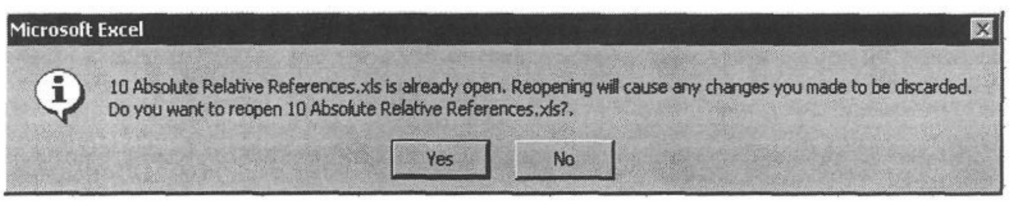


Figure 10-16 A menu flag.

D. Position your cursor in the template and press **Paste** to get this result:

row 240

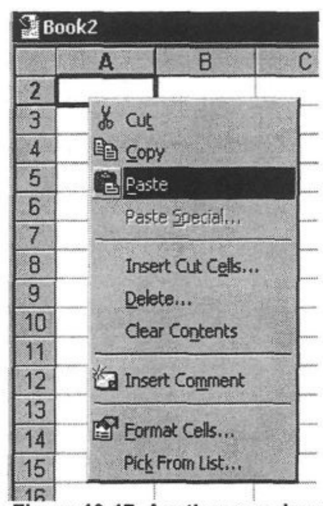


Figure 10-17 Another pop-down menu.

row 250

A	**B**	**C**	**D**
E	**F**	**G**	**H**
I	**J**	**K**	**L**
M	**N**	**O**	**P**
A	**A**	**A**	**A**
A	**A**	**A**	**A**
A	**A**	**A**	**A**
A	**A**	**A**	**A**
=$B$241	=$B$241	=$B$241	=$B$241
=$B$241	=$B$241	=$B$241	=$B$241
=$B$241	=$B$241	=$B$241	=$B$241
=$B$241	=$B$241	=$B$241	=$B$241

Figure 10-18 The CUT and PASTE, COPIED Array

row 260

CIRCULAR REFERENCE

A	B	C	D	E	F	G	H	I	J	K	L	M	N

CIRCULAR REFERENCE

The circular reference is intentional in this file.

You will get this error message when you open the file. Click on the x to cancel this message if it occurs.

Figure 11-1 The circular reference pop-up flag.

In Tools, Options... set Iterations to 1.

Try different numbers in the highlighted cell and press **[F9]** (calculate) several times to see the answer in the "Output" cell quit changing (converge). row 20

Input	+	0.05*Output	=	Output
1	+	0.0526316	=	1.0526316

The circular reference may be used, at times, to advantage. One example is the P-delta effect that takes place in columns and slender walls. If a column is already bent and an axial load is placed on it, it will bend more. This is because the load times its distance from the centerline at the bowed part of the column creates an additional moment which bends the column further. In a template, this relationship becomes a circular reference which will converge in about four iterations. row 30

e	**24**	in	load eccentricity
P	**100**	k	load
L	**12**	ft	length of column
E	**29000**	k/in^2	modulus of elasticity
I	**50**	in^4	moment of inertia
$M_{1\,2}$	2603.2	k-ft	moment at top and bottom of column
L /2	6.0	ft	where L /2 = x
D	0.032	ft	h / 371
	0.388	in	
	203.2	k-ft	additional moment
M_D	2606.5	k-ft	

row 40

Try different numbers in the highlighted cell and press **[F9]** (calculate) several times to see the answer in the "Output" cell "converge." row 50

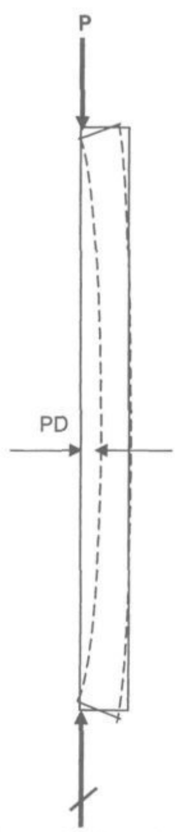


Figure 11-2 Using a circular reference to calculate the PΔ effect.

row 60

LOGIC
BOOLEAN ALGEBRA AND THE "IF" STATEMENT

A B C D E F G H I J K L M N

OVERVIEW

Math operators <, >, =, <=, >=

Dog 3 unit
Fox 4 unit

Result 1 logic
=Dog<Fox
3 Dog(s) < 4 Fox(s)

IF statements
Result_2 More foxes
=IF(Result,"More foxes","More dogs")

The Boolean statement may be contained within the IF statement
quantity 2 unit
2 Foxes string

formula text formula
=IF(quantity=1 , "1 Fox" , FIXED(quantity,0,TRUE) & " Foxes")

It could also return the result of a formula within the IF statement or reference a result from outside of the statement and returned from within the IF statement.

A 1
B More foxes
C 2 Foxes
Answer More foxes

The equation using range names:
A =Dog<Fox
B =IF(Result,"More foxes","More dogs")
C =IF(quantity=1,"1 Fox",FIXED(quantity,0,TRUE)&" Foxes")

=IF (A, B, C)

Note: it is often wise to show the formula used. Another aid in constructing and reviewing spreadsheets is to show the numbers in a concatenated string.

In this case, the IF statement uses the Boolean output of another cell to return a text statement.

row 20

When using **MIN( )** and **MAX ( )** functions, where the logic value **true = 1**, the **1** must operate on another number to be recognized.

For example:
a. MIN(1, 2, 3) returns **2** if the **1** references a logic result
b. MIN(1*1, 2, 3) returns **1** because the logic result operates on another number

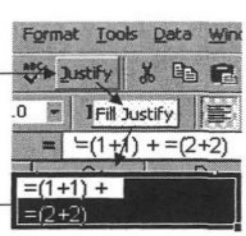
PARK AND CONCATENATE

An equation can be easily parked and copied without changing the references.
The following example equations use numbers only.

Equation D 2
Press the **[F2]** *edit key. Press the* **[Home]** *key to go to the front of the equation. Press the* **[Space Bar]** *to insert a space and turn the equation into plain text.* This yields: row 50
=(1+1)
Equation E 4
converts to =(2+2)

Create this equation, = D +E , by concatenation.
=(1+1) +
=(2+2)

Add the "+" operator now to keep the process simple or add *it later if you forget.*



row 60

Justify the range to create a text string on one row.
=(1+1) + =(2+2)

Figure 12-1 Concatenation with Justify command.

Now clean up the text by removing the = operator at mid-string and the space at the beginning of the string.
Equation F 6
Inserting a space or a comma in front of an equation also works well to put a malfunctioning equation on hold.

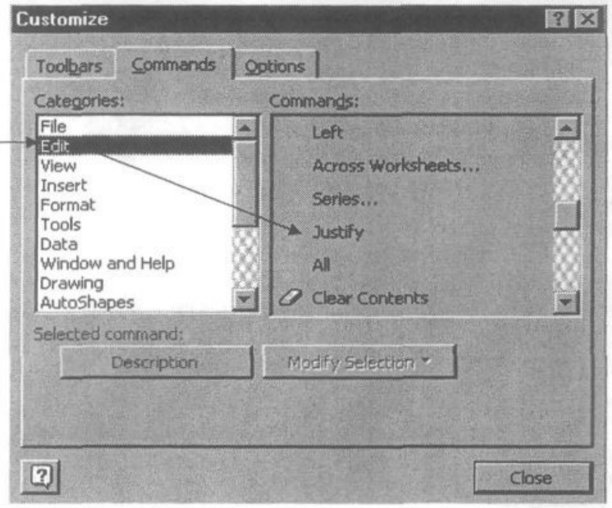
row 70

LOGIC
BOOLEAN ALGEBRA AND THE "IF" STATEMENT

A B C D E F G H I J K L M N

PARK, CONCATENATE, AND JUSTIFY

Add this button to your tool bar with
Tools, Customize, Commands, Edit, and Justify.
Drag this selection to the tool bar.



row 80

row 90

Figure 12-2 Adding a button to your tool bar in the Customize window.

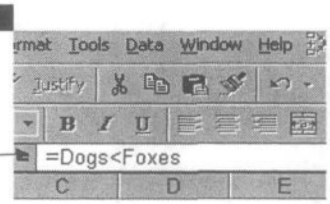
RANGE NAMES IN EQUATIONS

Dogs	**3**	unit
Foxes	**4**	unit
Result	1	logic

Show the equation with its range names, not cell R1C1 references.

1 parked and copied from above

Press the **[F2]** key to edit the equation in the equation window.



row 100

Figure 12-3 Range names in the formula bar.

Place the mouse pointer over or in front of the = sign and press the **[space bar]**.
Press **[Return]** and the equation under the cursor will turn from an
equation of cell references to an equation of range name references.
This equation has been parked as text and can be copied to a comments area.

1 =Dogs<Foxes

row 110

This method provides an audit trail or map of the logic process. A
good audit trail is important for verifying the template design.

OTHER LOGIC FUNCTIONS

IF (condition, x, y)
CHOOSE (x, v0, v1..vn)

VLOOKUP (x, range, column offset number)
HLOOKUP (x, range, row offset number)

row 120

MIN (range_1, range_2,..range_n, value, formula)
MAX (range_1, range_2,..range_n, value, formula)

#NOT# logical NOT
#AND# logical AND
#OR# logical OR

row 130

LOGIC
BOOLEAN ALGEBRA AND THE "IF" STATEMENT

A B C D E F G H I J K L M N

THE LOGIC SIEVE, BOOLEAN ALGEBRA, and BOOLEAN OPERATORS

Here we use two Boolean expressions to yield a 1 or a 0 for A, BB, or BC.

If one criteria or the other isn't met (i.e. Number not< 2), then at least one 0 is returned and B0*B0 or B0*B1 equals B0.

Three methods for creating a logic sieve are used in this example.
You may substitute numbers or formulas for A, B, and C in Example A.

Example A row 140

Number		3	Input
A		1	Number <= 1
B		1	Number <= 2
C		1	Number <= 3
Choice	A		Nested IF statement for text or numbers
	A		@Choose(x,n1..) for text or numbers

Example B row 150

A		1	0 < Number <= 1	A
B		0	1 < Number <= 2	B
C		0	2 < Number <= 3	C
Choice	A		Concatenated IF statements for text	

row 160

BOOLEAN TABLE

A	B	A<B	A>B	A=B	A<>B (A xor B)	A and B	A or B	not A	A nand B	A nor B
1	1	0	0	1	0	1	1	0	0	0
1	0	0	1	0	1	0	1	0	1	0
0	1	1	0	0	1	0	1	1	1	0
0	0	0	0	1	0	0	0	1	1	1
T	T	0	0	1	0	1	1	0	0	0
T	F	0	1	0	1	0	1	0	1	0
F	T	1	0	0	1	0	1	1	1	0
F	F	0	0	1	0	0	0	1	1	1

row 180

row 190

A B C D E F G H I J K L M N

D DIRECT DATABASE FUNCTIONS

The following are examples of spreadsheet direct database functions **D**.

Figure 13-1 The entry window and formula bar.

DSUM: the **D**function used to summarize total cost by Part # data

INPUT		CRITERIA		OUTPUT							
Part #	Amount	Part #	# Part	Sum	Avg	Count	Max	Min	Std	Var	
1	**$40.00**	1	1 Nuts								
2	**$40.00**	Part #	2 Bolts	$75.00	18.75	4	40	5.00	13	180	
1	**$20.00**	2	3 Washers	$100.00	33.33	3	55	5.00	21	439	
1	**$5.00**	Part #		$50.00	10.00	5	20	5.00	5	30	row 20
2	**$55.00**	3									
2	**$5.00**			$225.00							
3	**$5.00**										
3	**$10.00**										
1	**$10.00**										
3	**$10.00**										
3	**$20.00**										
3	**$5.00**										
	$225.00										

NOTES: Data range includes Part # and Amount

Criteria range includes the field name Part # and the part number immediately below

The D function is set up in a manner similar to data base input range, criteria range, and output range

SORT THE SAMPLE DATABASE

The **DATABASE** file serves as a working example for database commands and **D** database functions.

Item	Description	Quantity
N12	#12 nut	2000
N10	#10 nut	1500
B10	#10 bolt	1800
B12	#12 bolt	1700
W10	#10 washer	2100
W12	#12 washer	1800
N6	#6 nut	2000
N8	#8 nut	1500
B6	#6 bolt	1800
B8	#8 bolt	1700
W6	#6 washer	2100
W8	#8 washer	1800

The first column is an item stock description of the part.
The second column is a description the type of p
The third column is the quantity on hand.

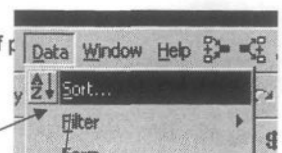
Highlight the database first and then click on the Data button and then Sort.

row 40

Note that although the headings were not included in the highlighted area, they show up in the drop-down menu.

You can choose to sort by a name in the Header row or by entering the cell address at the top of the row.

Item	Description	Quantity
N12	#12 nut	2000
N10	#10 nut	1500
B10	#10 bolt	1800
B12	#12 bolt	1700
W10	#10 washer	2100
W12	#12 washer	1800
N6	#6 nut	2000
N8	#8 nut	1500
B6	#6 bolt	1800
B8	#8 bolt	1700
W6	#6 washer	2100
W8	#8 washer	1800



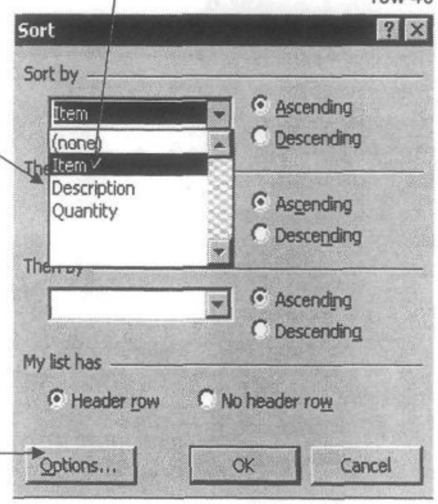


Figure 13-2 The Data, Sort window.

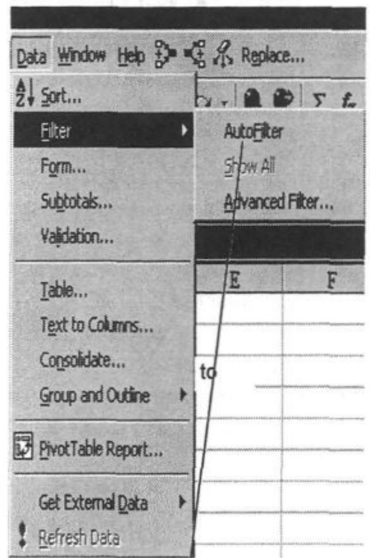
row 60

A B C D E F G H I J K L M N

FILTER THE SAMPLE DATABASE

Item	Description	Quantity
N12	#12 nut	2000
N10	#10 nut	1500
B10	#10 bolt	1800
W8	#8 washer	800
N8	#8 nut	900
N8	#8 nut	600
B12	#12 bolt	1700
W10	#10 washer	2100
W12	#12 washer	1800
N6	#6 nut	2000
N8	#8 nut	1500
B6	#6 bolt	1800
B8	#8 bolt	1700
W6	#6 washer	2100
W8	#8 washer	1800

In lieu of using the **D** functions, you can use the Data Filter command.



row 70

row 80

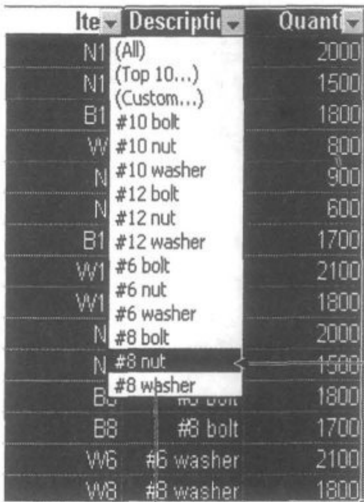
Item	Description	Quantity
N12	#12 nut	2000
N10	#10 nut	1500
B10	#10 bolt	1800
W8	#8 washer	800
N8	#8 nut	900
N8	#8 nut	600
B12	#12 bolt	1700
W10	#10 washer	2100
W12	#12 washer	1800
N6	#6 nut	2000
N8	#8 nut	1500
B6	#6 bolt	1800
B8	#8 bolt	1700
W6	#6 washer	2100
W8	#8 washer	1800

row 90

Figure 13-3 The data toolbar amd output. row 100

row 110

FILTER THE SAMPLE DATABASE -- Continued

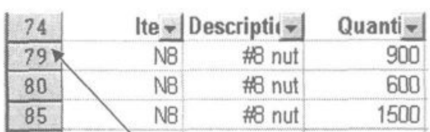


Click on one of the buttons to select an item.

row 120

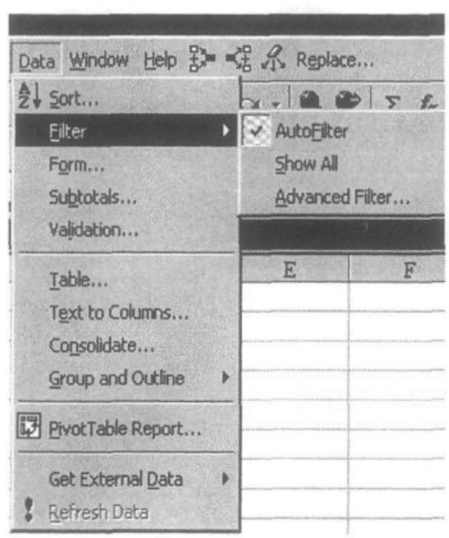
to get

row 130



notice that the spreadsheet has contracted by several rows

row 140



You can return the database to its original form by selecting (All) or clicking on Data, Filter and click on the check mark to disable the AutoFilter tool, or click on the Show All command.

row 150

Figure 13-4 The filtering process in the Data toolbar menu system.

row 160

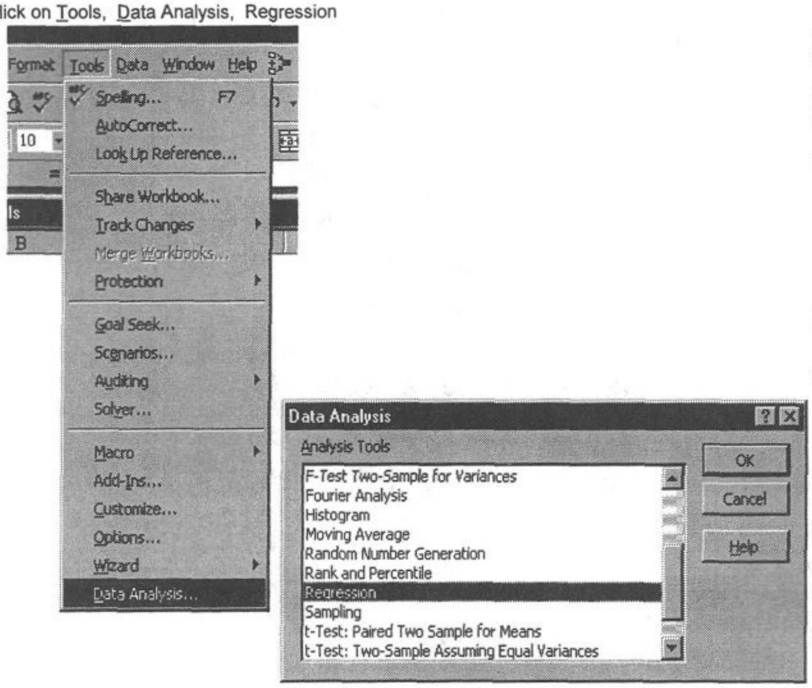
REGRESSION ANALYSIS

A B C D E F G H I J K L M N

GETTING STARTED

This spreadsheet tool calculates by the "least squares" method.

Click on Tools, Data Analysis, Regression



Definition:

Y = mX + b describes a straight line on a graph

where:

- Y — values plotted along the vertical Y axis
- m — slope of the line
- X — values plotted along the horizontal X-axis
- b — the Y-axis intercept; the point at which the line starts for a given value of X and Y along the slope m

row 20

Definition: $Y = m_1X_1 + m_2X_2 + b$

where: Y — the y variable depends upon values of X_1 and X_2 for a single line

row 30

NOTE: Some references use the equation y = a + bx. where **a** is the **Y** intercept and **b** is the slope. This can get a bit confusing.

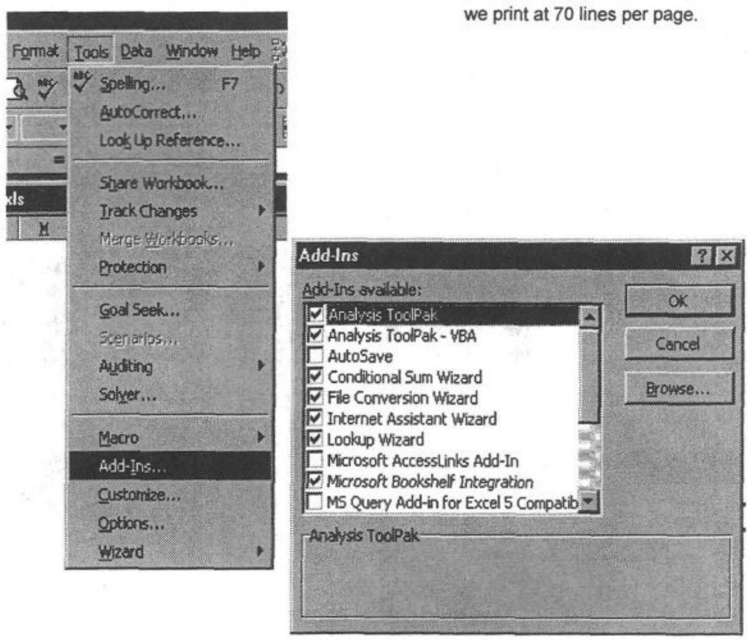
Note: Capitalized **X** and **Y** refer to actual plot values. Lower case **x** and **y** are the distances from the actual plot to the calculated values.

row 40

Figure 14-1 The Analysis window.

If the Data Analysis selection is not on your Tools drop down menu, go to Add-Ins in the Tools drop down menu and click on Analysis ToolPak

NOTE: This template is printed at roughly 80 lines per page because of the tables of calculations. Normally, we print at 70 lines per page.



row 50

row 60

Figure 14-2 The Add-Ins window.

row 70

ENGINEERING with the SPREADSHEET

14 Regression Analysis.xls

A B C D E F G H I J K L M N

AN EXAMPLE

Analyze the following data used in calibrating a string gage.

The quickest way to get results is to use the Regression tool.
The solution is an attempt to fit a curve to the data.

Note that the resulting table does not change with adjustments to the data.

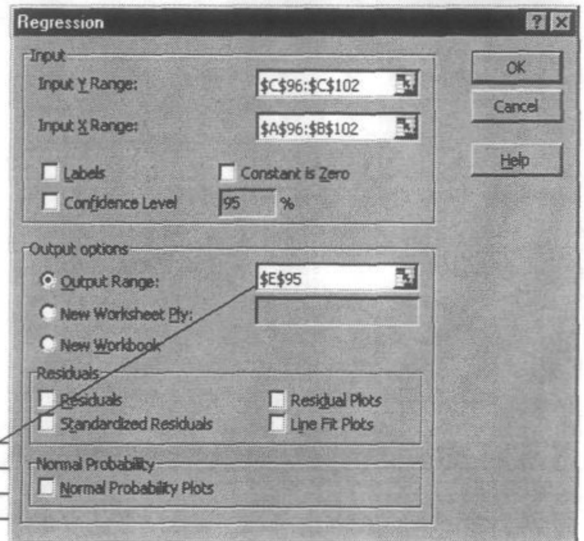


Figure 14-3 The Regression analysis window.

row 80

to read the entire label(s), increase the column width

row 90

In terms of y = mx + b

String 1	x^2	Distance	compare	SUMMARY OUTPUT	
4010	16080100	0.00	0.044		
2863	8194479	0.25	0.152	*Regression Statistics*	
1783	3177306	0.50	0.492	Multiple R	0.9902058
1097	1202312	0.75	0.827	R Square	0.9805075
682	464988	1.00	1.075	Adjusted R S	0.9707613
399	159281	1.25	1.264	Standard Er	0.0923469
213	45369	1.50	1.396	Observation	7

row 100

x — x^2 — y data

X Variable 1 X Variable 2

variables must be arrayed in this order -- do not reverse

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.7158882	0.857944	100.6037	0.00038
Residual	4	0.0341118	0.008528		
Total	6	1.75			

Labels cut short by column width

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95*	*Upper 95*	*Lower 95*	*Upper 95.0%*
Intercept	1.5563964	0.0816755	19.05585	4.47E-05	1.32963	1.78316	1.32963	1.78316
X Variable 1	-0.0007731	0.0001111	-6.96165	0.002238	-0.0011	-0.0005	-0.0011	-0.0005
X Variable 2	9.873E-08	2.614E-08	3.776497	0.019495	2.6E-08	1.7E-07	2.6E-08	1.7E-07

b

m_1

m_2

The Distance curve is the raw data.

The compare curve is the distance calculated using the values resulting values from the regression analysis.

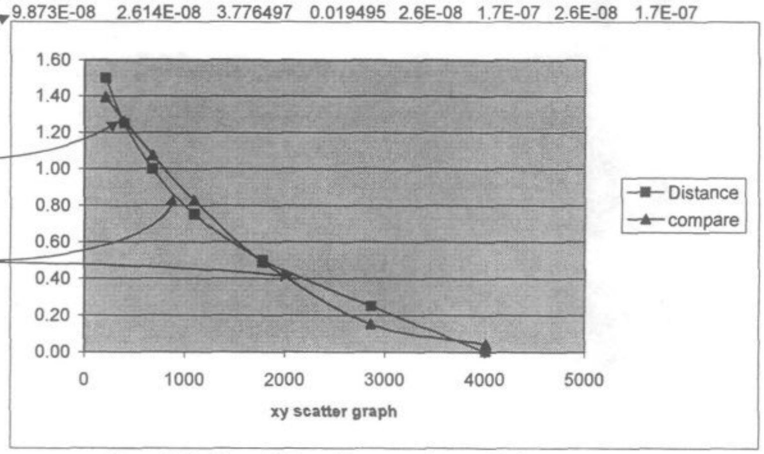


Figure 14-4 Curve fitting with regression analysis.

Now that we have all of this data, what does it mean? The following pages address the information presented by the regression tool and the **linest** function.

row 130

REGRESSION ANALYSIS

A	B	C	D	E	F	G	H	I	J	K	L	M	N

STRAIGHT LINE REGRESSION ANALYSIS -- LEAST SQUARES

Straight Line Regression Analysis **Y = mX + b** Where a least squares line is plotted using the values of x and y from the gage readings.

					x	y	x^2	y^2			
X	Y	X^2	Y^2	XY	$X - X_m$	$Y - Y_m$	$(X - X_m)^2$	$(Y - Y_m)^2$	straight line x	y	
53	45	2809	2025	2385	2.1	11.1	4.2	123.2	22	24.9	
36	43	1296	1849	1548	19.1	13.1	362.9	171.6	89	88.1	
88	89	7744	7921	7832	33.0	32.9	1085.7	1082.4			
84	79	7056	6241	6636	29.0	22.9	838.1	524.4			
86	84	7396	7056	7224	31.0	27.9	957.9	778.4			
64	66	4096	4356	4224	9.0	9.9	80.1	98.0			row 140
45	49	2025	2401	2205	10.1	7.1	101.0	50.4			
48	48	2304	2304	2304	7.1	8.1	49.7	65.6			
39	43	1521	1849	1677	16.1	13.1	257.6	171.6			
67	76	4489	5776	5092	12.0	19.9	142.8	396.0			
54	59	2916	3481	3186	1.1	2.9	1.1	8.4			
73	77	5329	5929	5621	18.0	20.9	322.2	436.8			
65	56	4225	3136	3640	10.0	0.1	99.0	0.0			
29	28	841	784	812	26.1	28.1	678.6	789.6			
52	51	2704	2601	2652	3.1	5.1	9.3	26.0			
22	27	484	729	594	33.1	29.1	1092.3	846.8			row 150
76	76	5776	5776	5776	21.0	19.9	438.9	396.0			
32	34	1024	1156	1088	23.1	22.1	531.3	488.4			
51	60	2601	3600	3060	4.1	3.9	16.4	15.2			
37	32	1369	1024	1184	18.1	24.1	325.8	580.8			
1101	1122	68005	69994	68740	325.2	322.2	7394.95	7049.8			
				-61766							

n **20** each Sxy = 6974

X_m	Y_m	XY_m
55.05	*56.1*	*3437*

Solve for the equations:

SY = m SX + n b

SXY b SX + m SX^2

for m $\frac{n * (Sxi\ yi) - Sxi\ Syi}{n * Sxi^2 - (Sxi)^2} =$ $\frac{1374800 \quad 1235322}{1360100 \quad 1212201}$

m **0.94306**

for b $\frac{Sx_i^2\ Sy_i - Sx_i\ Sy_i}{n * Sx_i^2 - (Sx_i)^2} =$ $\frac{76301610 \quad 75682740}{1360100 \quad 1212201}$

b **4.184410**

SUMMARY OUTPUT

Regression Statistics row 160

Multiple R	0.965872	
R Square	**0.932909**	< r2 is the correlation of estimated and actual y values
Adjusted R §	0.929182	
Standard En	**5.126058**	< standard error for the y estimate
Observation:	20	

degrees of freedom n - k

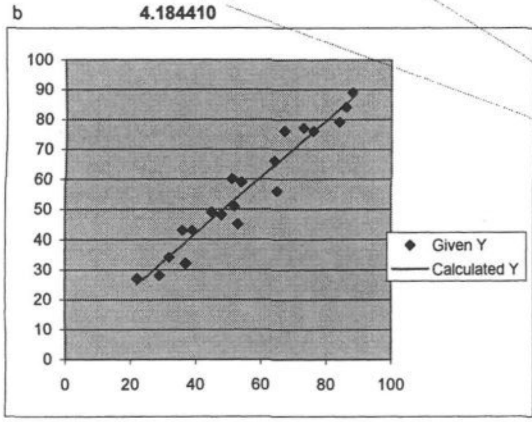
the F statistic to determine the degree of chance

ANOVA

	df	*SS*	*MS*	*F*	*gnificance F*	
Regression	1	6576.824	6576.82	***250.29***	5.3E-12	
Residual	18	472.9765	26.2765			row 170
Total	19	7049.8				

Note: move table labels for easier reading

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4.1844096	3.475932	1.203824	0.24425	-3.1183	11.4871	-3.1183	11.487
X Variable 1	0.9430625	0.05961	15.82066	5.3E-12	0.81783	1.0683	0.81783	1.0683



linest	m_1	b	
slope m	0.94306	4.184	y intercept
standard error se	0.05961	3.476	standard error for the coefficient m
R Square, r^2	**0.93291**	**5.126**	standard error for the y estimate
chance relation F	***250.293***	***18***	degrees of freedom n - k
SS Regression	6577	472.98	SS Residual, SSE

Figure 14-5 The straight line regression analysis process.. row 190

A B C D E F G H I J K L M N

STRAIGHT LINE REGRESSION ANALYSIS -- LEAST SQUARES Continued

The Long Hand Approach

n	20 each		number of samples		
k	**2** each		number of constants in the equation		
SSE	$S(Y - Y_m)^2 - b_1 / n(nSXY - SX\,SY)$				
SSE	7049.8	-0.0471531	1374800	-1101.00	1122.00
SSE	**472.98**				
s^2	SSE / (n - k)	472.98 /		18	
s^2	26.276				

$$r = \frac{n\,SXY - S\,X\;SY}{\sqrt{(n\,S\,X^2 - (SX)^2)\;(n\,SY^2 - (SY)^2)}}$$

$$r = \frac{1374800 \quad -1101 \quad 1122}{\sqrt{1360100 \quad -1212201 \quad 1399880 \quad -1258884}}$$

$$r = \frac{139478}{\sqrt{147899 \quad 140996}}$$

r	**0.966**	
r^2	**0.933**	R square

$$S_{YX} = \sqrt{\frac{Sy^2 - mSxy}{n - k}}$$

$$S_{YX} = \sqrt{\frac{7049.8 \quad -0.9430625 \quad 6974}{20 \quad -2}}$$

S_{YX}	**5.1261**	standard error of estimate

$$s^2_Y = \frac{Sy^2}{n - 1} = \frac{7049.8}{20 \quad -1}$$

s^2_Y	**371**	estimated total variance
s_Y	**19.3**	standard deviation

$$s_b = S_{YX} / \sqrt{Sx^2} \qquad 5.1261 / \sqrt{7395}$$

s_b	**0.0596**	error of regression coefficient

where: $Y_c = mX + b$

Y_c	the computed/expected value of y
X_m Y_m	the mean value(s) of X and Y
x y	deviations from their means $x = X - X_m$ and $y = Y - Y_m$
b	the y-axis intercept
m	slope of the line $(y_2 - y_1) / (x_1 - x_2)$
SSE	sum of squares for error = $S(Y - Y_m)^2$
df	degrees of freedom n - k row 200

where:

n	number of samples
k	number of constants in the equation, hence: $y = mx + b$ m and b = 2 constants; $y = m_1 + m_2 + b$ 3 constants
Sx^2	Sx^2 represents standard error of regression coefficient: the dispersion of X values around their mean.
r^2	compares estimated and actual y-values value ranges from 0 to 1 with 1 being a perfect correlation also known as R Square
Syx	Standard Error of Estimate of the dependent variable Y regressed against the independent variable(s) X
sey	standard error of the y estimate row 220
se	the standard error values for the coefficients m1, m2, etc.
s_b, se_b	Standard Error of the Regression Coefficient which is a measure of the sampling error in b.
t	describes the sampling distribution of a deviation from the population mean divided by the standard error

row 230

ssresid	the sum of the squared differences for estimated y y values and the actual y values for each point sum (y estimated - y actual)^2 $S(Y - Y_c)^2$ called the residual sum of the squares

the $(Y - Y_c)$'s above the line roughly equal the sum of the $(Y - Y_c)$'s below the line hence: $S(Y - Y_c) = 0$

row 250

STRAIGHT LINE REGRESSION ANALYSIS -- LEAST SQUARES Continued

s $\sqrt{\dfrac{S(X = X_m)^2}{n-1}}$ $\sqrt{\dfrac{7394.95}{19}}$

s	**19.7**		standard deviation
X_m	55.05		from above
	X	Y	
X_m - s	35.3	0	
	35.3	90	
X_m + s	74.8	0	
	74.8	90	
count	**13**		data points between the s cursors
%	68.4 %		13 points / n = 19 * 100

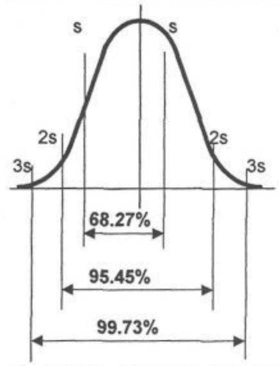


Figure 14-6 Standard deviations.

row 260

S_f S_{YX} $\sqrt{1 + 1/n + x^2 / Sx^2}$

5.1261 $\sqrt{\quad 1 \quad 0.0500 \quad x^2 / \quad 7394.95}$ F

X	**55**	sample value for X
S_f	**5.253**	standard error of forecast
		Spurr and Bonini pg 472

s, s standard deviation, standard measure of dispersion row 270

ssreg the sum of the squared differences for the actual values and the average y values for each point
sum (y actual - y average)^2
called the <u>regression sum of squares</u>

Standard Error of an Individual Forecast row 280

X	x	x^2	S_{YX}	S_f	S_f 95%	Y_c	S_f + 95%	S_f - 95%
15	-40.05	1604.00	5.1261	5.77	12.116	18.330	30.447	6.214
35	-20.05	402.00	5.1261	5.39	11.312	37.192	48.504	25.879
55	-0.05	0.00	5.1261	5.25	11.031	56.053	67.083	45.022
75	19.95	398.00	5.1261	5.39	11.310	74.914	86.224	63.604
95	39.95	1596.00	5.1261	5.77	12.111	93.775	105.887	81.664

where the value 2.10 * SYX and Sf comes from the table **VALUES of t** for Probability P see row 412

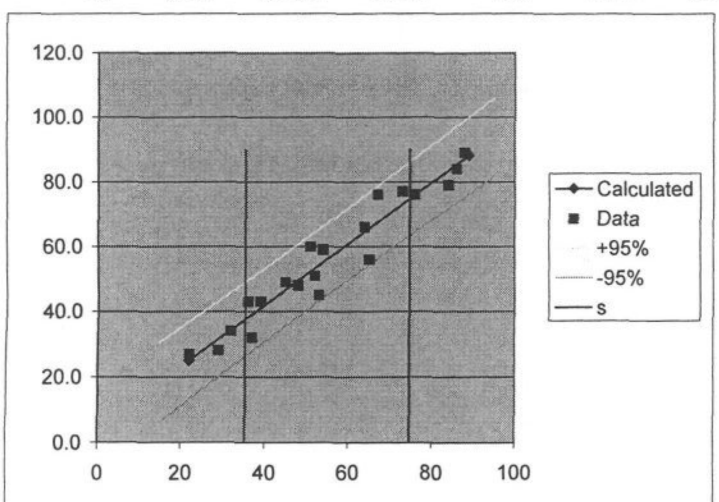


Figure 14-8 Regression analysis with the least squares concept.

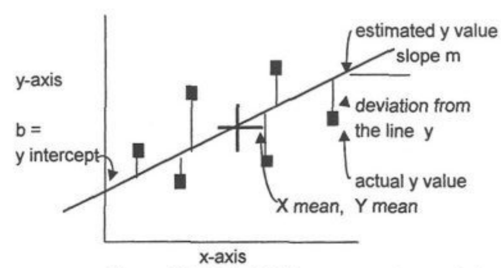


Figure 14-7 Straight line regression analysis.

row 290

row 300

total sum of squares
regression sum of squares + residual sum of the squares

F statistic determines whether the observed relationship between dependent and independent variables occurs by chance. Always positive.

row 310

A	B	C	D	E	F	G	H	I	J	K	L	M	N

LINEST VALUE

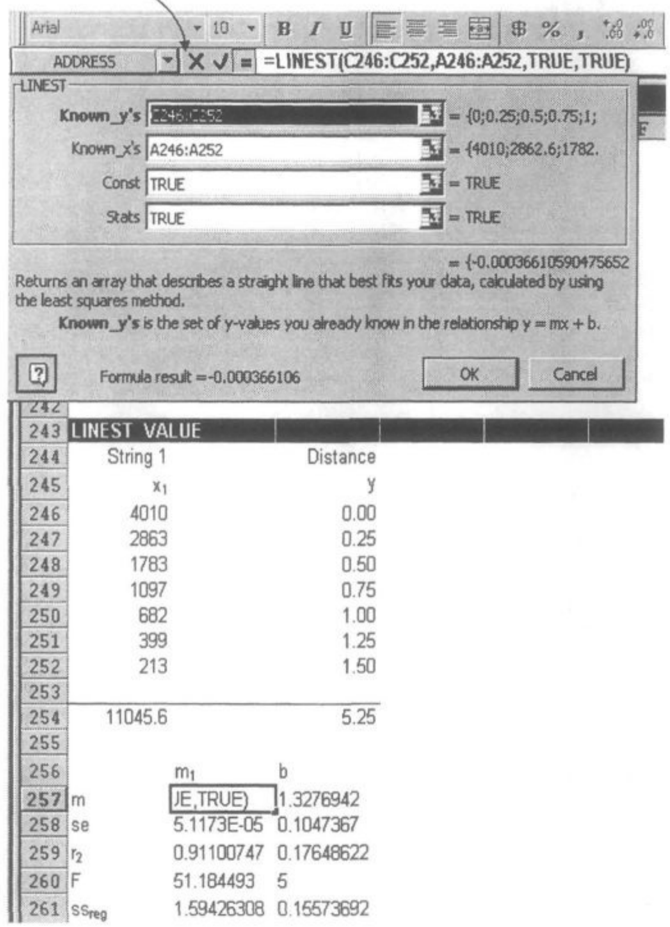
The **linest** function is the simpler, easier, and more dynamic way to do straight line, multiple straight line, and curvilinear regression analysis.
You can fit a straight or curved line and watch the **linest** function change to reflect your iterations.

String 1		Distance
X_1		Y
4010		0.00
2863		0.25
1783		0.50
1097		0.75
682		1.00
399		1.25
213		1.50
11045.6		5.25

linest	m_1	b
m	-0.0003661	1.3276942
se	5.117E-05	0.1047367
r_2	0.9110075	0.1764862
F	51.184493	5
ss_{reg}	1.5942631	0.1557369

To get help with the equation entry, click on the "=" sign in front of the edit bar.

row 320



row 330

row 340

row 350

Figure 14-9 The Linest value process.

row 360

row 370

LINEST VALUE -- Continued

To utilize the **linest** tool, first select an area to edit or input the formula and then park it with a space in front of the "=" sign.

String 1	Distance
x_1	y
4010	0.00
2863	0.25
1783	0.50
1097	0.75
682	1.00
399	1.25
213	1.50
11045.6	5.25

	m_1	b
m	=linest(D247:D253,B247:B253,true,true)	
se		
r_2		
F		
ss_{reg}		

↓ Describe an array with your cursor and press the [F2] key.

	m_1	b
m	=LINEST(D247:D253,B247:B253,TRUE,TRUE)	
se		
r_2		
F		
ss_{reg}		

↓ Remove the " ' " and space in front of the "=" sign.
Press the [Ctrl] [Shift] [Return] keys at the same time.

	m_1	b
m	' =LINEST(D247:D253,B247:B253,TRUE,TRUE)	
se		
r_2		
F		
ss_{reg}		

↓ To get this result:

	m_1	b
m	-0.0003661	1.3276942
se	5.1173E-05	0.1047367
r_2	0.91100747	0.17648622
F	51.184493	5
ss_{reg}	1.59426308	0.15573692

Figure 14-11 The Linest process.

Degrees of freedom	P = 0.1 tail 0.05	P = 0.05	
1	6.314	12.706	
2	2.900	4.303	
3	2.330	3.182	
4	2.132	2.776	row 380
5	2.015	2.571	
6	1.943	2.447	
7	1.895	2.365	
8	1.860	2.306	
9	1.833	2.262	
10	1.812	2.228	
11	1.796	2.201	
12	1.782	2.179	
13	1.771	2.160	row 390
14	1.761	2.145	
15	1.753	2.131	
16	1.746	2.120	
17	1.740	2.110	
18	1.734	2.101	
19	1.729	2.093	
20	1.725	2.086	
21	1.721	2.080	
22	1.717	2.074	row 400
23	1.714	2.069	
24	1.711	2.064	
25	1.708	2.060	
26	1.706	2.056	
27	1.703	2.052	
28	1.701	2.048	
29	1.699	2.045	
30	1.697	2.042	
infinity	1.645	1.960	row 410

Figure 14-10 Values of t and probability P.

row 420

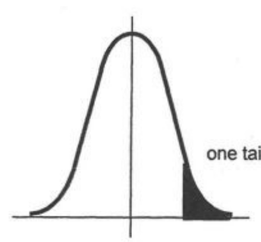


Figure 14-12 The one tail curve.

row 430

MULTI-STRAIGHT LINE REGRESSION ANALYSIS

We will use fabricated data for this example

plot the mean of the two values through the data scatter

Area	Height	Value										
X_1	X_2	Y	X_1^2	X_2^2	Y^2	X_1 Y	X_2 Y	$X_1 X_2$	X_1	X_2	Y	
14.7	155	4.1	216.1	24025	16.81	60.27	635.5	2278.5	9.921	105.03	3.048	4.06738
14.2	155	3.9	201.6	24025	15.21	55.38	604.5	2201	16.535	175.05	5.08	
12.7	158	3.2	161.3	24964	10.24	40.64	505.6	2006.6	24.803	262.58	7.620	
13.8	158	2.9	190.4	24964	8.41	40.02	458.2	2180.4				
14.4	155	3.9	207.4	24025	15.21	56.16	604.5	2232				
17.4	157	4.1	302.8	24649	16.81	71.34	643.7	2731.8				row 440
21.8	172	5.8	475.2	29584	33.64	126.44	997.6	3749.6				
14.0	170	5.1	196.0	28900	26.01	71.4	867	2380				
17.5	175	6.8	306.3	30625	46.24	119	1190	3062.5				
23.0	185	6.8	529.0	34225	46.24	156.4	1258	4255				
18.3	185	6.5	334.9	34225	42.25	118.95	1202.5	3385.5				
19.4	205	7.0	376.4	42025	49.00	135.8	1435	3977				
15.2	215	5.8	231.0	46225	33.64	88.16	1247	3268				
18.3	195	5.1	334.9	38025	26.01	93.33	994.5	3568.5				
21.7	178	5.3	470.9	31684	28.09	115.01	943.4	3862.6				
16.7	160	4.9	278.9	25600	24.01	81.83	784	2672				row 450
13.6	205	6.0	185.0	42025	36.00	81.6	1230	2788				
14.5	190	5.3	210.3	36100	28.09	76.85	1007	2755				
12.1	203	4.8	146.4	41209	23.04	58.08	974.4	2456.3				
17.4	125	4.3	302.8	15625	18.49	74.82	537.5	2175				
330.7	3501	101.6	5657.41	622729	543.44	1721.48	18119.9	57985.3				
n	20											
mean												
X_{1m}	X_{2m}	Y_m	$X_{2m}\,x_1$	$X_{2m}\,x_2$	Y_m y	$Y_m\,x_1$	X_{2m} y	$X_{2m}\,x_1$				
16.535	175.05	5.08	5468.12	612850	516.13	1679.96	17785.08	57889.0				
			Sx_1^2	Sx_2^2	Sy^2	Sx_1y	Sx_2y	Sx_1x_2				row 460
			189.29	9879	27.312	41.524	334.82	96.3				

Long Hand Calculations

Simultaneous Equations for $y = m_1x_1 + m_2x_2 + b$

Sx_1 y	$= m_1\ x_1^2$	$+ m_2\ x_1\ x_2$
41.524	$= m_1$ *189.29*	$+ m_2$ *96.3*
Sx_2 y	$= m_1\ x_1\ x_2$	$+ m_2\ x_2^2$
334.82	$= m_1$ *96.3*	$+ m_2$ *9879*

linest	m_1	m_2	b	
slope m	**0.0319**	**0.2031**	**-3.8653**	y intercept
standard error se	0.007001	0.05058	1.44269	standard error for m
R Square, r^2	0.70007	0.69416	#N/A	standard error for the y est
chance relation F	19.83996	17	#N/A	degrees of freedom n - k
SS Regression	19.12031	8.19169	#N/A	SSE

multiply Sx_2y by →		1.966		row 470
to get	658.36	189.29	19425	
subtract from Sx_1y				
to get	-616.83	0	-19328.676	
m1	**0.2031**			
m2	**0.0319**			
	Y mean	$-m_1X_1$ mean	$-m_2X_2$ mean	
	5.08	3.359	5.586	
b	**-3.8653**			row 480

To predict y with inputs for x1 and x2

x_1	**15**		
x_2	**180**		
y	3.047	5.744	-3.865
y	4.926		

n	20 each	number of samples from above
k	**3** each	number of constants in the regression equation

row 490

A B C D E F G H I J K L M N

MULTI-STRAIGHT LINE REGRESSION ANALYSIS -- Continued

Syx $\sqrt{\dfrac{Sy^2 - m_1Sx_1y - m_2Sx_2y}{n - k}}$

Syx $\sqrt{\dfrac{27.312 \quad -0.2031 \; 41.52 \quad -0.0319 \; 334.82}{20 \quad -3}}$

Syx **0.6942** standard error of estimate

S_f $S_{YX} \sqrt{1 + 1/n + x^2 / Sx^2}$

s^2_Y $\dfrac{Sy^2}{n - 1} = \dfrac{27.312}{19}$

s^2_Y **1.437** estimated total variance

R^2 $1 - S^2yx / s^2_Y$

R^2 **0.6648** coefficient of multiple determination also known as R Square

R **0.8153**

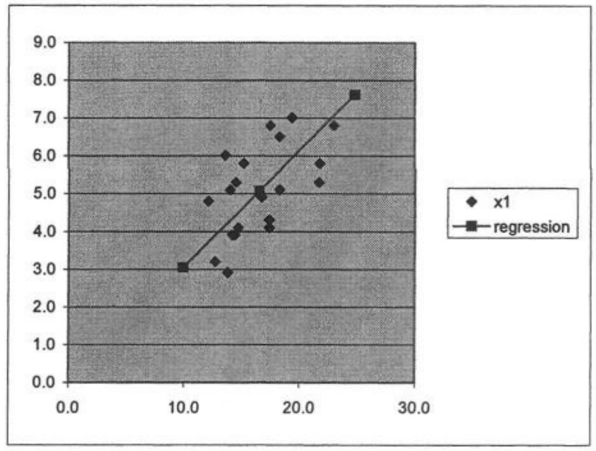


Figure 14-13 Regression Graph

row 500

row 510

Beta Coefficients

b_1 $b_1 \sqrt{\dfrac{Sx_1^2}{Sy^2}}$

b_1 $0.2031 \sqrt{\dfrac{189.29}{27.312}}$

b_1 **0.535**

b_2 $b_2 \sqrt{\dfrac{Sx_2^2}{Sy^2}}$

b_2 $0.0319 \sqrt{\dfrac{9879}{27.312}}$

b_2 **0.607**

b is a pure number representing the net regression coefficient expressed in units of its own standard deviation.

row 520

Compare these values to see which values, X_1 or X_2, have greater significance.

Standard Error of Regression Coefficient

r^2_{12} $\dfrac{(Sx_1x_2)^2}{(Sx^2_1)(S^2x_2)}$ $\dfrac{96.3 \text{ ^2}}{189.29 \quad 9879}$

r^2_{12} **0.0050**

sm_1 $\dfrac{Syx}{\sqrt{Sx^2_1 \; (1 - r^2_{12})}}$

sm_1 $\dfrac{0.694}{\sqrt{189.29 \quad 0.9950}}$

sm_1 **0.0506** Standard Error of the Regression Coefficient

sm_2 $\dfrac{Syx}{\sqrt{Sx_2^2 \; (1 - r^2_{12})}}$

sm_2 $\dfrac{0.694}{\sqrt{9879 \quad 0.9950}}$

sm_2 **0.0070**

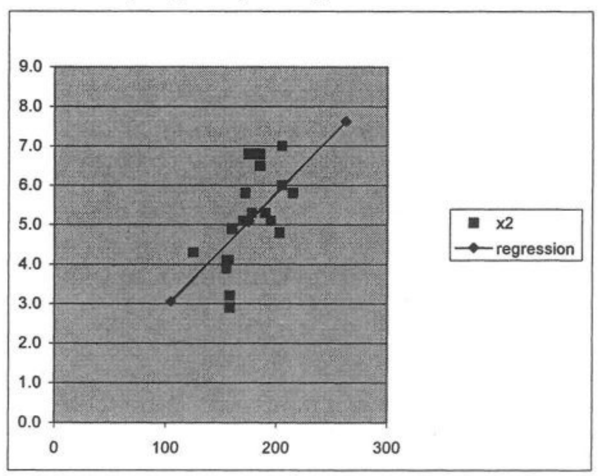


Figure 14-14 Regression Graph No. 2

row 530

row 540

m_1 **4.016** standard errors from $B_1 = 0$
0.2031 m1 / 0.0506 sm1

m_2 **4.558**

For n - k degrees of freedom, the one tailed t value is 2.567 at a significance of 0.01.
Both m_1 and m_2 are greater than 2.567 at a significance of 0.01.

row 550

A	B	C	D	E	F	G	H	I	J	K	L	M	N
THE F COEFFICIENT													
Are the methods different enough from each other to be significant?													
Method	1	2	3	4									
scores	65	75	59	94			4225	5625	3481	8836			
	87	69	78	89			7569	4761	6084	7921			
	73	83	67	80			5329	6889	4489	6400			
	79	81	62	88			6241	6561	3844	7744			
	81	72	83				6561	5184	6889				
	69	79	76				4761	6241	5776				
		90						8100					row 560
T X	454	549	425	351	**1779**	SX^2	34686	43361	30563	30901	**139511**		
group mean	75.67	78.43	70.83	87.75									
T_m $(SX)^2$	34353	43057	30104	30800	**138314.4**								

n	**23**		
p	**4**	groups, populations	
CM	(SX)2 / n	1779	23
CM	**137602**	correction for the mean	
Total SS	$S(X - X_m)^2$ - CM	139511	137602
Total SS	**1909.2**		
SST	$Sn(T_m - X)^2$ = ST^2/n -CM	138314	137602
SST	**712.6**		
SSE	Total SS - SST	1909.2	712.6
SSE	**1196.6**		
Mean squares for treatment and error			
MST		712.6	3
	237.5		
MSE	SSE / (n - p)	1196.6	19
MSE	**63.0**		
F	MST / MSE	237.53	62.98
F	**3.77**		

to find the F statistic for

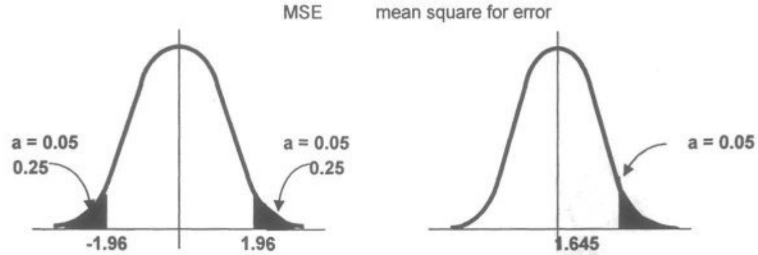
n_1	p - 1	
	3	
n_2	n - p	
	19	
for $F_{.05}$	3.13	OK 3.13 < 3.77

X_{mm} overall mean denoted in text books as X with double bars on top

CM correction for the mean

Total SS SST + SSE row 569
SST sum of squares for treatment
SSE pooled sum of squares of the deviations, sum of the squares for error

MST mean squares for treatment
MSE mean square for error



two tailed statistical test rejection region shaded

single tailed statistical test rejection region shaded

Figure 14-15 Two tailed and single tailed curves.

F MST / MSE the chance relation between data groups and within a group the F statistic determines whether the observed relationship between dependent and independent variables occurs by chance. Always positive.

n_1 factor for the groups in the F statistic

n_2 factor for the number of observations within a number of groups

r^2 the coefficient of correlation between y and x, A measure correlation varies from 0 to 1 with 1 being the best correlation

row 610

THE F COEFFICIENT -- Continued

Data Table from above

	Method					**linest** m →				b
score #	1	2	3	4	slope m	0.008781	0	-0.0508	-0.1236	0
1	65	75	59	94	standard error se	0	0	0	0	0
2	87	69	78	89	R Square, r_2	1	0	#N/A	#N/A	#N/A
3	73	83	67	80	chance relation F	**#NUM!**	0	#N/A	#N/A	#N/A
4	79	81	62	88	SS Regression	5	0	#N/A	#N/A	#N/A
5	81	72	83	0		the chance relation **F** in this linest is not valid				
6	69	79	76	0						
7	0	90	0	0 ←	linest must have 0's as place holders					

row 620

						linest				
	6	7	6	4	slope m	-0.0566	-0.124712	0.12109	0.1367	-3.9531
	75.7	78.4	70.8	87.8	standard error se	0.011377	0.064868	0.06152	0.06516	5.63671
					R Square, r_2	0.971371	0.633097	#N/A	#N/A	#N/A
					chance relation F	**16.96454**	2	#N/A	#N/A	#N/A
					SS Regression	27.19838	0.801624	#N/A	#N/A	#N/A

row 630

Sort each group in ascending order before using linest

score #	1	2	3	4		1		2		3		4
1	65	69	59	80	61	0.156	66	0.276105	55	0.44606	80	0.84615
2	69	72	62	88	95	7.908	90	7.467074	95	8.16128	95	4.04715
3	73	75	67	89								
4	79	79	76	94								
5	81	81	78									
6	87	83	83									
7		90										
7	6	7	6	4								
3.0	75.8	65.9	71.3	88.8								

Group 1	**linest**	
slope m	0.228	-13.752
standard error se	0.011358	0.86357
R Square, r_2	0.990171	0.20736
chance relation F	402.9767	4
SS Regression	17.328	0.172

row 640

Group 2	**linest**	
slope m	0.299624	-19.499
standard error se	0.021989	1.73062
R Square, r_2	0.973777	0.38321
chance relation F	185.6726	5
SS Regression	27.26576	0.73424

row 650

Group 3	**linest**	
slope m	0.19288	-10.162
standard error se	0.015308	1.09
R Square, r_2	0.975424	0.33
chance relation F	158.7618	4.00
SS Regression	17.06992	0.43

Group 4	**linest**	
slope m	0.2134	-16.226
standard error se	0.045213	3.97393
R Square, r_2	0.917618	0.45
chance relation F	22.27711	2
SS Regression	4.588089	0.41191

row 660

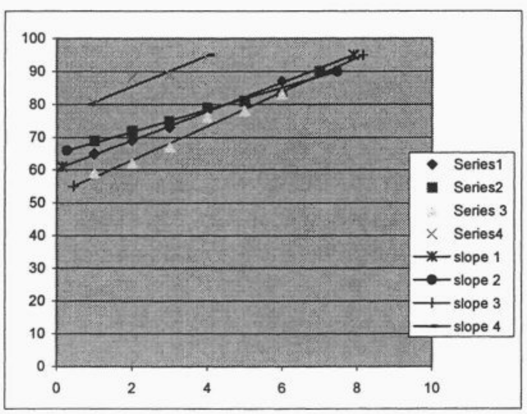


Figure 14-16 A comparason of methods.

row 670

A B C D E F G H I J K L M N

CURVILINEAR REGRESSION ANALYSIS

And now, for the real reason that I got into this essay.

Record the readings of a string gage at about 0.25 inch intervals. This string gage uses a linear potentiometer but the readings from linear potentiometers and LVDT's are never quite linear. To interpret readings from the gage between the calibration measurements, we create the equation that can plot a straight line through the scatter of points and give fairly accurate results.

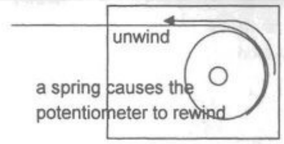


Figure 14-17 A diagram of the string gage.

The creation of an equation to fit these points is fitted essentially by hand. We use the **linest** function to help us fit this curve. **Linest** is dynamic -- as you change your values, **linest** re-computes its value.

r^2 the correlation of estimated and actual y values

The r^2 value is of critical value.

Note: an r^2 greater than 0.95 is usually acceptable

LVDT linear voltage displacement transducer an instrument which uses a power supply to create and AC voltage. The measurement is made by the position of a plunger within a coil whose voltage changes as the plunger moves. Measurements must be "normalized" to be truly accurate.

String 1		Distance			
x_1	$x_2 = x_1^{1.01}$	y	curve	x1 mean	y mean
4010	4357	0.00	4011	3627	0
2863	3100	0.25	2861	1578	0.75
1783	1921	0.50	1782	-471	1.5
1097	1176	0.75	1098		
682	728	1.00	683		
399	424	1.25	400		
213	225	1.50	212		

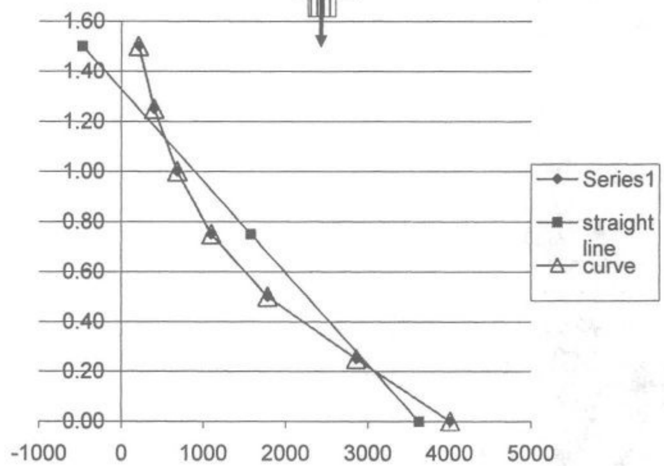
power of	**1.01**
n	7

linest x1

m	-0.0003661	1.3276942
se	5.117E-05	0.1047367
r^2	**0.9110075**	0.1764862
F	51.184493	5
ss_{reg}	1.5942631	0.1557369

linest x_1 + $x_1^{\text{power of}}$

m	0.0326723	-0.0359284	1.7598648
se	0.0045917	0.0049979	0.068505
r^2	**0.993484**	0.0533924	#N/A
F	304.93727	4	#N/A
ss_{reg}	1.738597	0.011403	#N/A

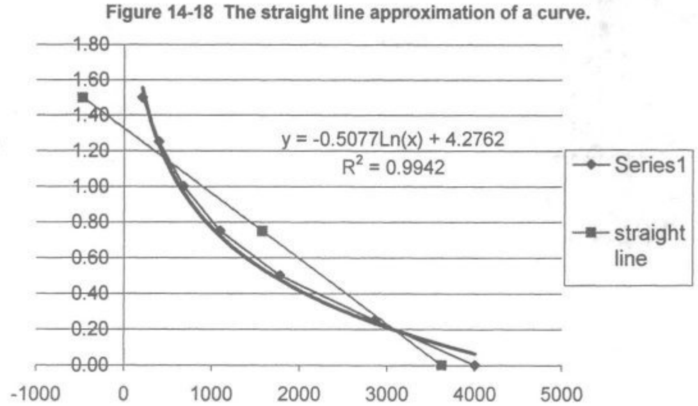


row 700

row 710

Figure 14-18 The straight line approximation of a curve.

This plot can be also be fitted with Excel's add trendline feature in the graph pop up menu.
Click on the curve of actual values and select add trendline.
You have the option of displaying the formula and the value for r^2 on the graph.



row 720

Figure 14-19 Using Excel's add trendline function to fit a curve.

row 730

TAKEDOWN

Kraft Pulping Building Modifications

A	B	C	D	E	F	G	H	I	J	K	L	M	N

KRAFT PULPING 24 May 84

This is a sample from an actual job.
Loads must be tallied and factored for column and foundation design.

Column A2 Loads Take Down

	A2	DL	LL	New Piping	Existing Piping	Sum		
Roof		6.45		0	0	6.45		
		2	wall			2		
							8.45	row 20
Conveyor flr		21.5	floor	2.6	9.4	33.5		
		2	21.5	conveyor		23.5		
			8.6	8.4		17	82.45	
Operating flr		21.5			6.6	28.1		
		2	wall			2		
							112.55	
Mezzanine		6.5			36.4	42.9		
		31	at ES			31		
					9.6	9.6	196.05	
Ground floor								row 30
Figure 15-1 Structure Elevation		92.95	30.1	11	62	196.05	196.05	

row 40

row 50

row 60

A B C D E F G H I J K L M N

POLE FOUNDATION -- LATERAL BEARING TYPE FOUNDATION

This template uses the "shooting method" of converging two equations which depend upon each other for values.

P	**0.5**	k	Applied lateral force, kips
h	**4.0**	ft	distance from ground surface to P, ft
q	**266**	psf/ft	allowable soil-brg UBC Table 18-I-A / IBC Table 1804.2 / psf/ft
b	**1.00**	ft 12"	diameter or diagonal dimension of a 0.71' square post, ft

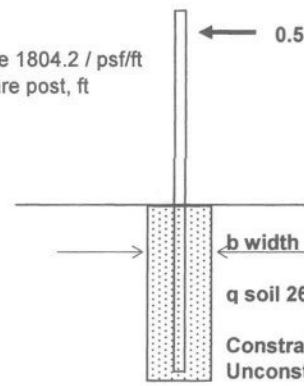


Figure 16-1 POLE FOUNDATION ELEVATION

Constrained

$S_3 = q * d$ row 20

$d^2 = 4.25 * P * 1000 * h / (S_3 * b)$

$d^2 = 4.25 * P * 1000 * h / (q * d * b)$

$d^3 = 4.25 * P * 1000 * h / (q * b)$

$d = (4.25 * P * 1000 * h / (q * b))^{1/3}$

d	3.19	ft	$(4.25 * P * 1000 * h / (q * b))^{1/3}$
			(4.25 * 0.5 * 1000 * 4.0 /(266 * 1.00))^(1/3)
	0.376	k	weight
			$(1.00/2)^2 * \pi * 3.19 * 0.150$
	0.093	cy	concrete
			$(1.00/2)^2 * \pi * 3.19 / 27$

Unconstrained at Top

S_1	445	psf	q * d_est / 3
A	3	ft	$2.34 * P * 1000 / (S_1 * b)$
d_u	5.02	ft	$A/2 * (1 + (1 + 4.36 * h/A)^{1/2})$
converge	100.0	%	the difference in d_u for the last 2 iterative calculations = 0.00 ft
			100 - 0.00
	0.591	k	weight (row 40)
			$(1.00/2)^2 * \pi * 5.02 * 0.150$
	0.146	cy	concrete
			$(1.00/2)^2 * \pi * 5.02 / 27$

NOTES

See UBC 1806.7.2.1 equation 6-1 NonConstrained, 6-2 Constrained / IBC 1805.7.2.1 equations 18-1, 2, and 3 / and Table 18-I-A / IBC 1804.2 / Allowable Foundation and Lateral Pressure for typical allowable lateral pressures.

The solution for this answer is iterative. Typically -- vary the estimated depth **d_est** to be greater than the required depth for constrained or unconstrained conditions. If you have a maximum depth which must not be exceeded, vary the width **b**. row 50

Width **b** is the diameter of a round post or the diagonal dimension of a square post (or footing). Hence, **b** for a 3'-0" round footing is 3.0 but for a 3'-0" square footing b is (3^2+3^2)^0.5 = 4.24'

P * h = moment to overturn the foundation

UBC 1806.7.2.1 d / IBC Table 1804.2 footnote d / states that allowable stresses and soil-bearing values may be increased 33% when combining vertical loads with wind/earthquake loads or when lateral loads are acting alone. Footnote 3 in Table 18-I-A / IBC 1804.3.1 / allows a 100% lateral bearing increase for poles not adversely affected by a 1/2" lateral translation at the top of the footing. Use judgement when increasing the 2x multiplier by another 33%.

Depth **d_est** is the depth of embedment in the earth not to exceed 12 ft when computing lateral pressures **S_1** or **S_3**.

UBC Table 18-I-A note 3 / IBC 1804.3.1 / limits lateral bearing value increase to 15 x designated value. Current designated value = 266 psf/ft. Max value = 3990 psf. However, depth "d" used for computing lateral pressure is limited to 12'. Hence, lateral pressure is limited to 3192 psf.

row 70

A	B	C	D	E	F	G	H	I	J	K	L	M	N

THE SHOOTING METHOD

ITERATIVE CALCULATIONS FOR **UNCONSTRAINED** FOOTING

d_est **5.00** ft ESTIMATED embedment, 5.00 ft. for pressure

443.33	445.70	444.89	444.36	444.82	444.84	444.68	444.73	444.77	445	445	445	445	444.74
2.69	2.68	2.68	2.69	2.68	2.68	2.68	2.68	2.68	2.7	2.7	2.7	2.7	2.68
5.03	5.01	5.01	5.02	5.02	5.02	5.02	5.02	5.02	5.0	5.0	5.0	5.0	5.02
													0.00

$q*MINA(D_EST,12) /3
266 * MINA(5.00, 12) /3 ↓

2.34 * $P * 1000 /(A89 * $B)
2.34 * 0.51 * 1000 /(443.33 * 1.00) ↓

A90 /2 * (1 + (1+ 4.36 * $H /A90)^0.5)
2.69 /2 * (1 + (1 + 4.36 * 4.00 /2.69)^0.5)

$q * MINA(A91, 12) /3
266 * MINA(5.03, 12) /3 ↓

2.34 * $P * 1000 /(B89 * $B)
2.34 * 0.51 * 1000 /(445.70 * 1.00) ↓

B90 /2 * (1 + (1+ 4.36 * $H /B90)^0.5)
2.68 /2 * (1 + (1 + 4.36 * 4.00 /2.68)^0.5)

$q * MINA((A91 + B91) /2, 12) /3
266 * MINA((5.03 + 5.01) /2, 12) /3 ↓

in this row, a new depth of embedment is calculated

row 80

No convergence factor is applied to the math in these equations. Other equation sets require some sort of adjustment/convergence factor to achieve convergence. row 90

The notes below the inputs are not meant to represent the code. You will want to edit them to reflect your understanding of the code and soils engineering. They are included in the printout as an aid to the building department in reviewing these calculations.

Also, the code can be complicated at times and these notes help to bring all of the design issues together in one place. Otherwise, some of the fine but important points may be forgotten such as the 12' embedment limit.

WORKSHEET

row 100

Values for a lamp pole:

	Weights	h	cg	Seismic	area	cg	Wind
lamps	90	2	32.33	2910	3	32.33	97
brackets	42	0	31.33	1316	1	31.33	31
spar	100	1.33	30.665	3067	5	30.665	153
pole	558	30	15	8370	15	15	225
sum	790	33.33		15662			506.645
			M seismic 0.5	7831 lb-ft		M wind 18	9120 lb-ft

row 110

relative P 282.08 k wind
relative h 32.33 ft

row 120

row 130

NUMERICAL INTEGRATION

A B C D E F G H I J K L M N O P Q R S T U V W X Y

OVERVIEW

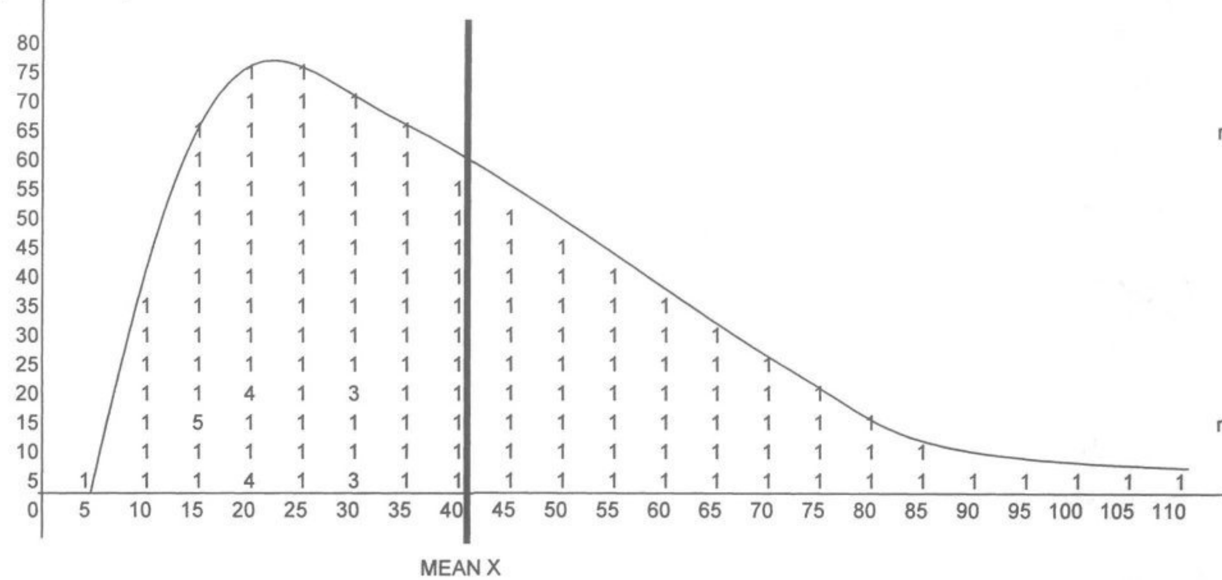
This template was originally created to design irregular footings.
It calculates I_{xx}, I_{yy}, I_{xy} and the centers of gravity.

Many engineering designs do not submit themselves to logic. They require numerical integration. Most of us do a rough type of numerical integration when we're balancing a fry pan on an uneven burner.

What is numerical integration? Well, for example, draw a curve on quadrule paper and a straight line below the curve. Now, determine the area below the curve. Count the squares between the curve and the straight line. Counting the squares is numerical integration. row 20

The following figure is a printout from the numerical integration template. It's for a skewed population sample.

row 30



row 40

Figure 17-1 Numerical integration of a population sample.

The area or population size is simply the number of filled cells. The center of gravity (or mean) is the balance point. It is calculated as the sum of all the individuals times their respective distances from the X or Y axis divided by the area (population). row 50

For the distance from the Y axis
Sum (each value * respective arm) /number of samples

value * 5 70 255 420 375 540 455 440 450 450 440 420 390 350 300 240 170 90 95 100 105 110
sum 162 =SUM(B28:W42)

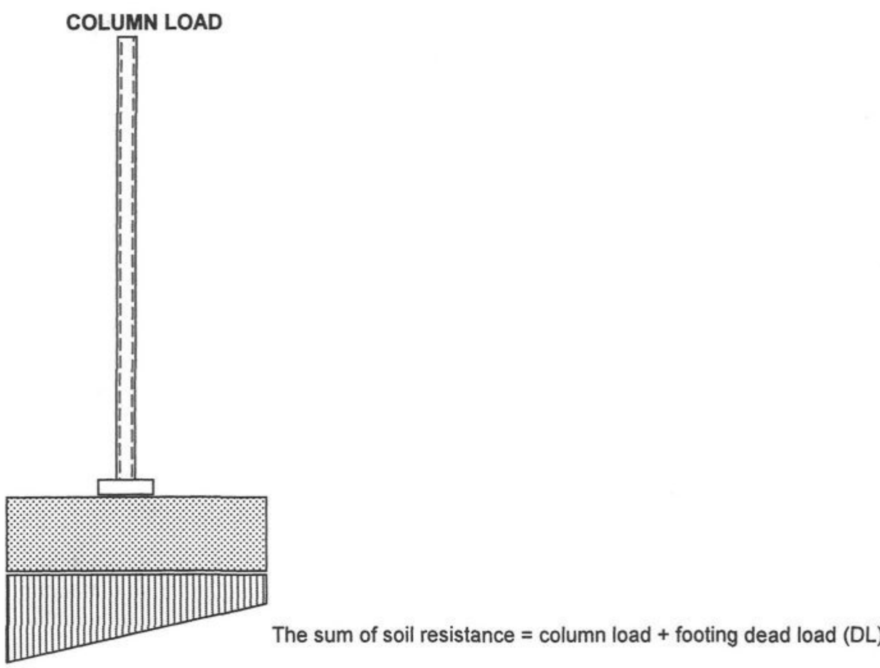
Mean X 39 =SUM(B56:W56)/B57

row 60

FOOTING DESIGN

That's the first step. The template was actually created to analyze irregularly shaped footings with eccentric loads. In real life, not all populations fit the bell shaped curve, nor can all footings be square or rectangular with the load in the middle.

In the template, the footing's shape is described by filling in a field of cells. Each spreadsheet cell represents an element which has a width, length, and center of gravity. The contribution from each element to the footing is calculated in several different formulas in rows below the field and compiled into values for other calculations. The end result is a close approximation to the formal calculus answer and it will work for our footing. row 70



row 80

row 90

Figure 17-2 An elevation view of the column and footing.

The soil pressure that resists the footing will vary. The simple form of the equation that describes this resistance at a given location beneath a rectangular footing is:

$$q \text{ lbs/ft}^2 = \frac{P \text{ lbs}}{\text{area ft}^2} \pm \frac{M \text{ lb-ft} * c \text{ ft}}{I \text{ ft}^4}$$

c — the distance from the extreme fiber to the center of gravity in the direction in question

CG — center of gravity

Ad^2 — spreadsheet notation is Ad^2

The interesting part of this equation is the variable **I**, the moment of inertia. This is the resistance to moment, the twisting force that tries to tip the footing into the soil. For this design, you won't find I in a book somewhere. You have to derive it.

row 110

FOOTING DESIGN -- Continued

You can explain this concept as analogous to a bicycle tire where the fat tire is harder to get going than the thin tire. The fat tire has more area of rubber out at the rim and, therefore, more moment of inertia, I.

Calculating I requires two equations that work with the field of cells shown. The first formula is:

$$I = Area * distance^2$$

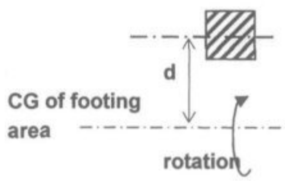


Figure 17-3 Rotation around the footing's center of gravity

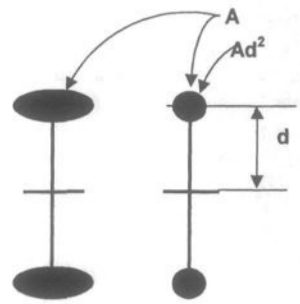


Figure 17-4 Bicycle tire profiles for a moment of inertia comparison.

row 120

This is a way of multiplying each element times the square of its distance from the footing's center of gravity. Here, the element essentially rotates about the footing's center of gravity.

row 130

This calculates a value of I for each element where the element rotates about its own axis.

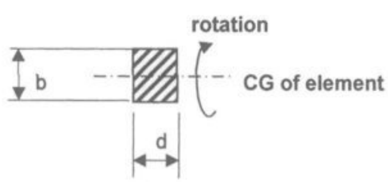
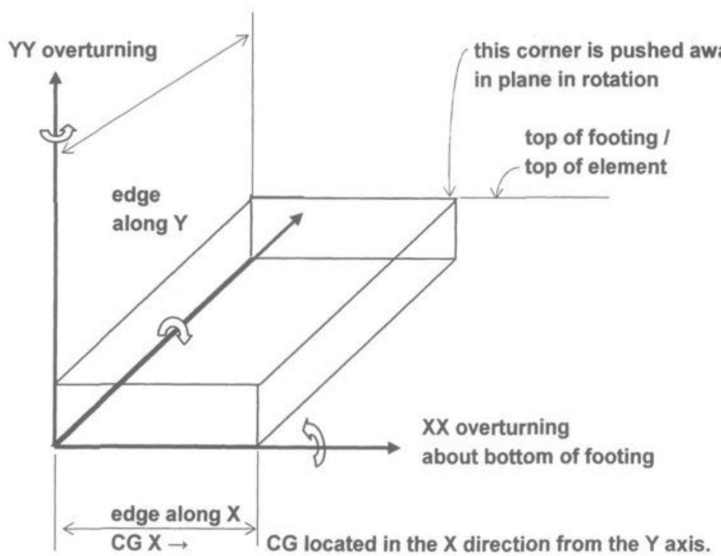


Figure 17-5 Rotation of an element around its own center of gravity.

The value of I for a rectangular element is:

$$I = b\,d^3 / 12$$

row 140



row 150

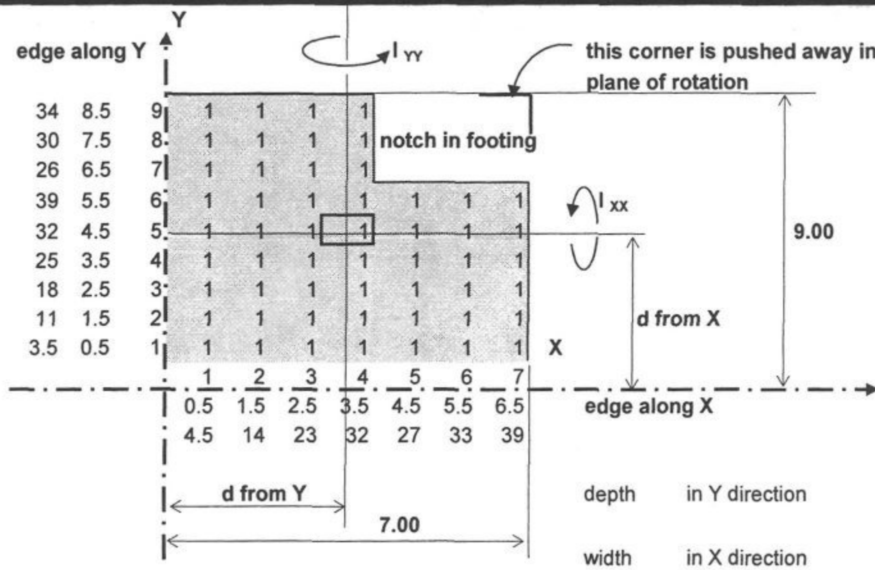
Figure 17-6 3D view of the footing.

row 160

A B C D E F G H I J K L M N O P Q R S T U V W X Y

FOOTING DESIGN -- Continued

This is easy to model with the spreadsheet. The two I's for a column of cells are computed in two rows of cells below the field. The values in those rows are summed in a convenient spot to the right of the rows. In this way, the values for all of the squares are counted like the squares on quadrule paper.



row 170

unit depth **1.00** ft

unit width **1.00** ft

depth in Y direction

Area **54** ft²

sum X*d 171 ft-ft²

width in X direction row 180

Figure 17-7 FOOTING PLAN VIEW

d_X could be the distance from the X axis or Y axis. Use descriptive range names and descriptions. This works better for you and others using your work.

CG X → **3.17** ft CG about Y axis

sum Y*d 216 ft-ft²

CG Y ↑ **4.00** ft CG about X axis

I_{XX} about X			d Ad²	4	16	16	16	16	0	0	0	bd³/12	0.1	0.1	0.1	0.1	0	0	0	
A d_X^2 ↑				3	9	9	9	9	0	0	0		0.1	0.1	0.1	0.1	0	0	0	row 190
				2	4	4	4	4	0	0	0		0.1	0.1	0.1	0.1	0	0	0	
				1	1	1	1	1	1	1	1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	
				0	0	0	0	0	0	0	0		0.1	0.1	0.1	0.1	0.1	0.1	0.1	
				-1	1	1	1	1	1	1	1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	
I_{XX} about X				-2	4	4	4	4	4	4	4		0.1	0.1	0.1	0.1	0.1	0.1	0.1	
sum I_{XX}	**338** ft⁴			-3	9	9	9	9	9	9	9		0.1	0.1	0.1	0.1	0.1	0.1	0.1	
about CG $_X$			333	-4	16	16	16	16	16	16	16	4.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	

I_{YY} about Y		d	-2.7	-1.7	-0.7	0.33	1.33	2.33	3.33										row 200
A d_Y^2		Ad²	7.1	2.8	0.4	0.1	0	0	0	b³d/12	0.1	0.1	0.1	0.1	0	0	0		
⟶			7.1	2.8	0.4	0.1	0	0	0		0.1	0.1	0.1	0.1	0	0	0		
			7.1	2.8	0.4	0.1	0	0	0		0.1	0.1	0.1	0.1	0	0	0		
			7.1	2.8	0.4	0.1	1.8	5.4	11		0.1	0.1	0.1	0.1	0.1	0.1	0.1		
			7.1	2.8	0.4	0.1	1.8	5.4	11		0.1	0.1	0.1	0.1	0.1	0.1	0.1		
			7.1	2.8	0.4	0.1	1.8	5.4	11		0.1	0.1	0.1	0.1	0.1	0.1	0.1		
I_{YY} about Y			7.1	2.8	0.4	0.1	1.8	5.4	11		0.1	0.1	0.1	0.1	0.1	0.1	0.1		
sum I_{YY}	**209** ft⁴		7.1	2.8	0.4	0.1	1.8	5.4	11		0.1	0.1	0.1	0.1	0.1	0.1	0.1		
about CG $_Y$		204	7.1	2.8	0.4	0.1	1.8	5.4	11	4.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1		

row 210

A B C D E F G H I J K L M N O P Q R S T U V W X Y

FOOTING DESIGN -- Continued

d from X	**4.5**	ft	location of column from the X axis ↑
d from Y	**4**	ft	location of column from the Y axis →
P	**24**	k	
M_X	-12.0	k-ft	moment about CG from X axis
M_Y	-20.0	k-ft	

c_X can also be **d from X** distance from the CG load to the extreme fiber in question at the top or bottom of the plan view

Keeping everything sorted out is easier with descriptive range names.

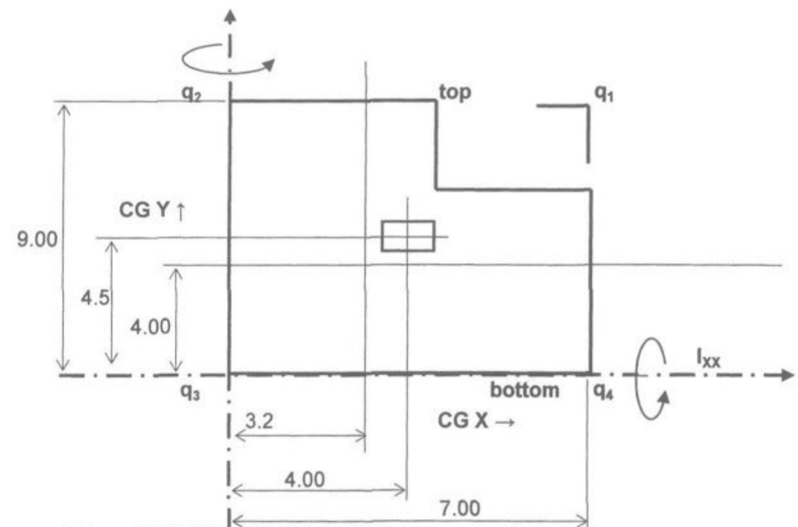


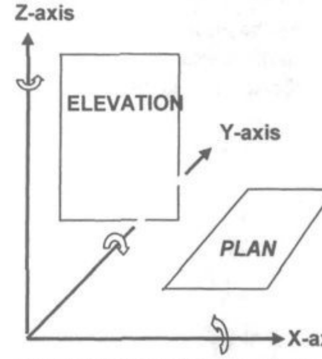
Figure 17-9 FOOTING PLAN VIEW

$$q\ \text{k/ft}^2 = \frac{P\ \text{k}}{\text{area ft}^2} \pm \frac{M_X\ \text{k-ft} * c_Y\ \text{ft}}{I_{XX}\ \text{ft}^4} \pm \frac{M_Y\ \text{k-ft} * c_X\ \text{ft}}{I_{YY}\ \text{ft}^4}$$

	P/area		$M_X c_Y / I_{XX}$		$M_Y c_X / I_{YY}$		
	24 / 54	-	-12 4.5 / 338	+	-20 3.00 / 209		
q_1	0.4	-	-0.2	+	-0.3	=	**0.3**
				-	-20 4.00 / 209		
q_2	0.4	-	-0.2	-	-0.4	=	**1**
		+	-12 4.5 / 338				
q_3	0.4	+	-0.2	-	-0.4	=	**0.67**
q_4	0.4	+	-0.2	+	-0.3	=	**0.00**

Other numerical integration applications can become more complex but the approach is much the same. Generally, fields of formulas calculate values which are compiled into an answer.

row 220



row 230

Figure 17-8 The right-hand rule.

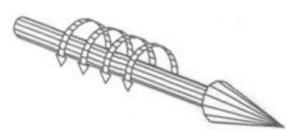


Figure 17-10 Simple view of the right-hand rule.

row 240

Wrap the fingers of your right hand around the arrow. Your thumb will point in the positive direction of the axis.

This rule is handy for installing screws, nuts, and bolts. Remember to use your right hand, point your thumb in the direction you want the bolt to go, and turn the bolt in the direction that your fingers point.

row 250

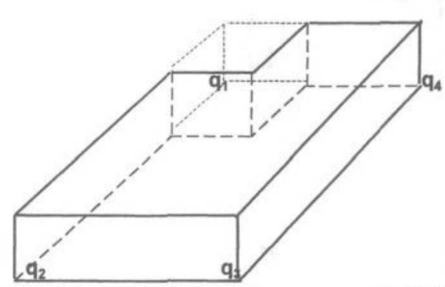


Figure 17-11 View of the footing.

row 260

NUMERICAL INTEGRATION for W8 X 31

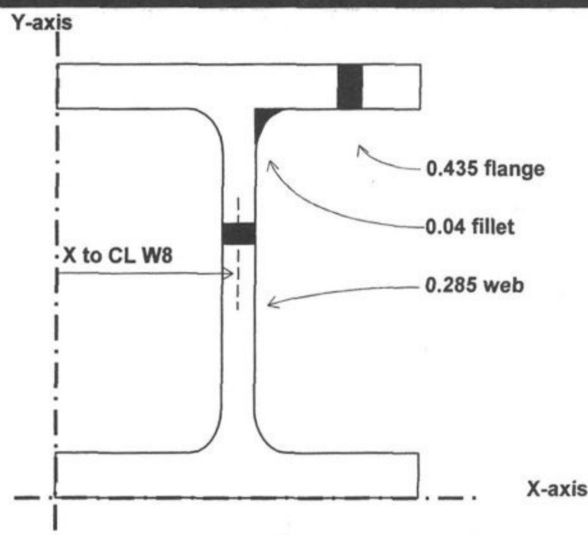
Scale factors of 0.5 inch and 0.5 inch were selected for the X and Y-axes. The flange thickness (0.435 inch) is divided by the scale factor so that the correct area of the flange for that segment of the flange length will be used by the model.

Note that the fillets are also approximated.

These values compare favorably with the values in *the Eighth Edition AISC Handbook.*

The template also calculates the stress at a chosen point.

Item	**W8 X 31**	
X Scale	**0.5**	adjust axis scales to fit as many areas
Y Scale	**0.5**	(rectangles) in to the model as possible



row 270

Figure 17-12 The profile of a wide flange beam. row 280

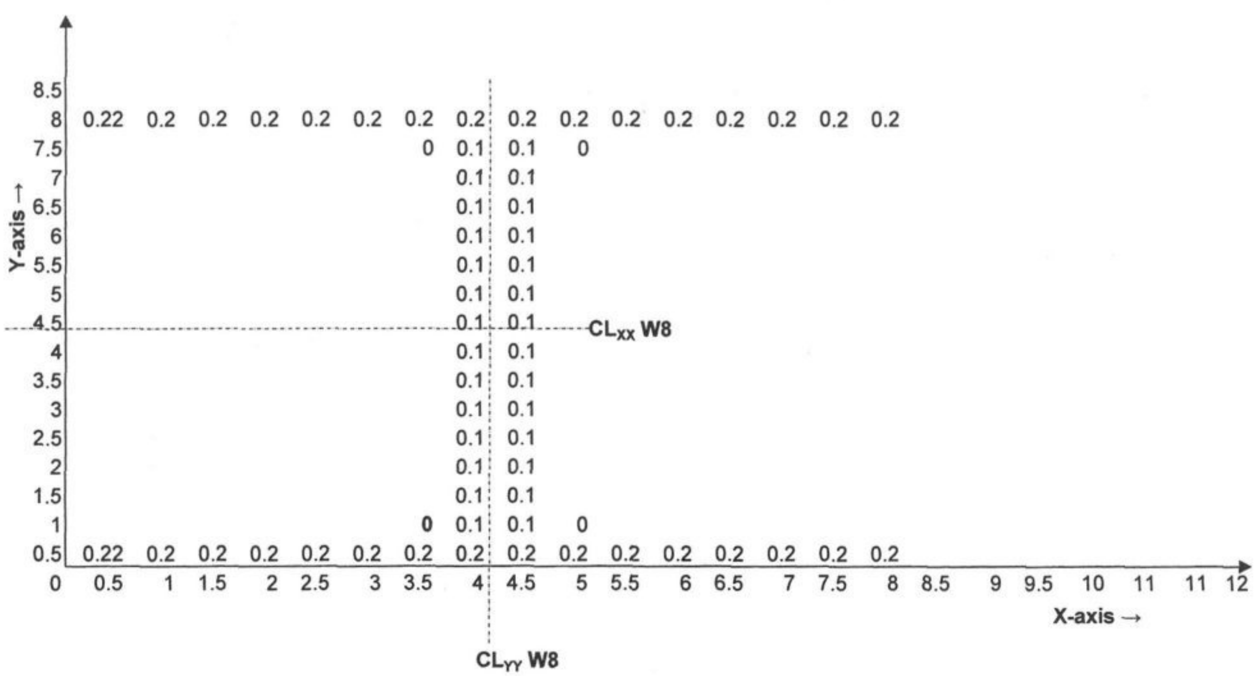


Figure 17-13 The profile of a wide flange beam.

row 310

NUMERICAL INTEGRATION

NUMERICAL INTEGRATION for W8 X 31 For I_{YY} about the Y axis

A B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
A sum	**9.12** in^2																						
X to CL																							
elements	0.25	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8	5.3	5.8	6.3	6.8	7.3	7.8	8.3	8.8	9.3	9.8	10	11	11
A elements	0.44	0.4	0.4	0.4	0.4	0.4	0.5	1.4	1.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0	0	0	0	0	0	0
AX	0.11	0.3	0.5	0.8	1	1.2	1.7	5.4	6.1	2.4	2.3	2.5	2.7	2.9	3.2	3.4	0	0	0	0	0	0	0
sum AX	36.5																						
CG from Y	**4** in																						
Ad^2 YY	0.03	0.2	0.7	1.3	2.2	3.3	5.4	20	26	12	12	14	17	20	23	26	0	0	0	0	0	0	0
	183																						
CG - X = d	3.75	3.3	2.8	2.3	1.8	1.3	0.8	0.3	-0.2	-0.7	-1.3	-1.8	-2.3	-2.8	-3.3	-3.8	-4.3	-4.8	-5.3	-5.8	-6.3	-6.8	-7
	6.12	4.6	3.3	2.2	1.3	0.7	0.3	0.1	0.1	0.3	0.7	1.3	2.2	3.3	4.6	6.1	0	0	0	0	0	0	0
$bd^3/12$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	0	0	0	0	0	0	0
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	100	100	100	100	100	100	##

I $edge_{YY}$	**183** in^4

Ad² NA 37.2

I_{YY}	**37.3** in^4

I_{YY} moment of inertia about the weak axis of a wide flange shape.

generally, taken as the moment to rotate a shape around the vertical, Y-axis

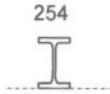
d usually, the distance from the neutral axis to the center of a finite element

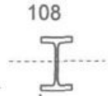
I_{XX} moment of inertia about the strong axis of a wide flange shape generally, taken as the moment to rotate a shape around the horizontal, X-axis

NUMERICAL INTEGRATION for W8 X 31 For I_{XX} about the X axis

Oriented vertically for rotation about the X-axis

Y	Y to CL elements ↓	A elements ↓	sum AY	I $edge_{XX}$ / Ad^2 XX		Ad^2 NA		$bd^3/12$	
8.5	8.25	0	0	0	-4.3	0	0	0	100
8	7.75	3.5	27	209	-3.8	49	0	8	8
7.5	7.25	0.2	1.6	12	-3.3	2.4	0	7.5	7.5
7	6.75	0.1	1	6.5	-2.8	1.1	0	7	7
6.5	6.25	0.1	0.9	5.6	-2.3	0.7	0	6.5	6.5
6	5.75	0.1	0.8	4.7	-1.8	0.4	0	6	6
5.5	5.25	0.1	0.7	3.9	-1.3	0.2	0	5.5	5.5
5	4.75	0.1	0.7	3.2	-0.8	0.1	0	5	5
4.5	4.25	0.1	0.6	2.6	-0.3	0	0	4.5	4.5
4	3.75	0.1	0.5	2	0.2	0	0	4	4
3.5	3.25	0.1	0.5	1.5	0.7	0.1	0	3.5	3.5
3	2.75	0.1	0.4	1.1	1.3	0.2	0	3	3
2.5	2.25	0.1	0.3	0.7	1.8	0.4	0	2.5	2.5
2	1.75	0.1	0.2	0.4	2.3	0.7	0	2	2
1.5	1.25	0.1	0.2	0.2	2.8	1.1	0	1.5	1.5
1	0.75	0.2	0.2	0.1	3.3	2.4	0	1	1
0.5	0.25	3.5	0.9	0.2	3.8	49	0	0.5	0.5
		9.1	36	254		108			





CG from X	I $edge_{XX}$	I_{XX}
4.00 IN	**254** in^4	**108** in^4

row 350

row 360

NUMERICAL INTEGRATION

NUMERICAL INTEGRATION for W8 X 31 For I_{XY} about NA_X and Na_Y

A–B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0.22	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0	0	0	0	0
7.5	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0.22	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0	0	0	0	0
0																							

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 11 11 12

Figure 17-14 An example of conditional formatting.

This is a good example of conditional formatting. It makes this table/calculation easier to read and troubleshoot. Conditional formatting is discussed on the next page and is used in several of the other templates in this manual.

CONDITIONAL FORMATTING

1	0	0
0.5	0.22	0.2
0		
	0.5	1

The 0 values have been formatted to be gray in color which may or may not show well on the printout.

The non-zero values have been formatted as black, bold on a yellow background which shows well on our HP LaserJet 6P. row 390

To apply conditional formatting, click on Format and Conditional formatting…

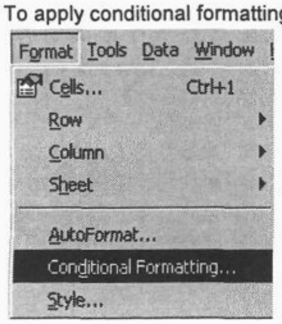


Figure 17-15 Drop down menu.

to get →

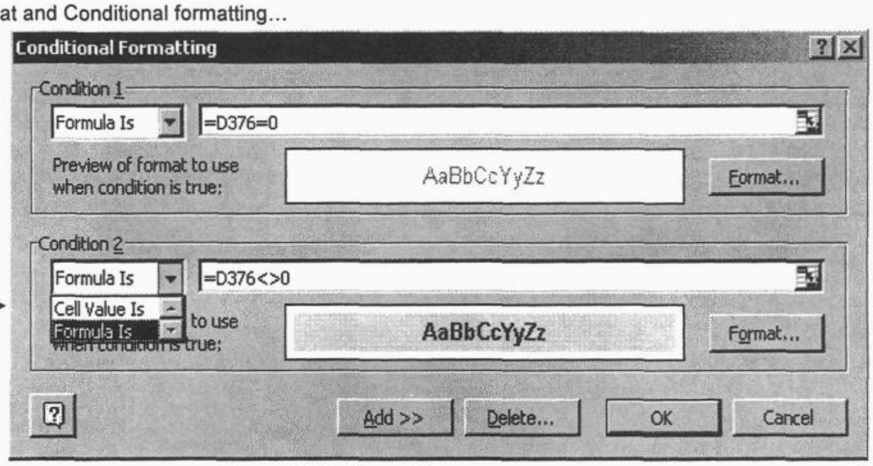


Figure 17-16 Cascading menu. row 410

NUMERICAL INTEGRATION

A B C D E F G H I J K L M N O P Q R S T U V W X Y

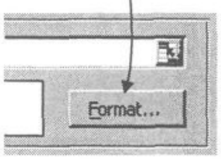
CONDITIONAL FORMATTING -- Continued

The cells in the wide flange profile above were formatted using two of the three possible formats in Conditional Formatting. Press **Add>>** for each additional condition and format.

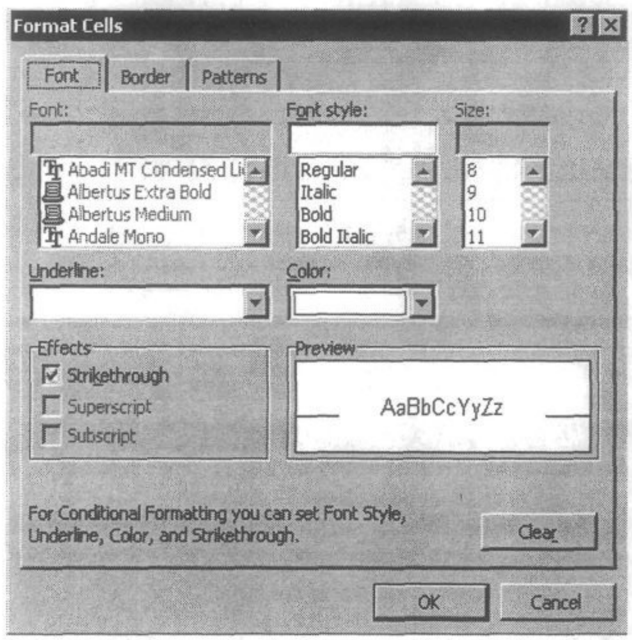
Entering the formula is the tricky part. Click on the  icon and then click on a cell. The values returned will be automatically absolutely referenced. To make these operate as relative references, use your mouse pointer to highlight the spot in front of the **$** and press the **[Backspace]** key.

row 420

To format the cell, press the format button



to get →



row 430

This menu operates more or less like the regular format menu.

row 440

Figure 17-17 The conditional formatting menu.

row 450

row 460

NUMERICAL INTEGRATION

NUMERICAL INTEGRATION for W8 X 31 For XY area

X Scale	*0.5*	*from above*
Y Scale	0.5	
CG from X	4.00 in	
CG from Y	4 in	

C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-3.06	-2.7	-2.2	-1.8	-1.4	-1	-0.6	-0.2	0.2	0.6	1	1.4	1.8	2.2	2.7	3.1	0	0	0	0	0	0	0
0	0	0	0	0	0	-0.1	-0.1	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0.1	0.1	-0.1	-0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
3.06	2.7	2.2	1.8	1.4	1	0.6	0.2	-0.2	-0.6	-1	-1.4	-1.8	-2.2	-2.7	-3.1	0	0	0	0	0	0	0

sum for I_{xy} 0.00 in^2

Figure 17-18 Locating the centers of gravity.

SUMMARY OF RESULTS

Area	9.1 in^2					
CG X	4.00 in	e_X	CG from X			
CG Y	4.00 in	e_Y	CG from Y			
I about	254 in^4		S top	32 in^3	rx	3.4 in
I_{XX}	108 in^4		S top	27 in^3	ry	2 in
I about	183 in^4		S lt/Y	366 in^3		
I_{YY}	37 in^4		S lt/N	11 in^3		
Ixy	0.0 in^4					

row 490

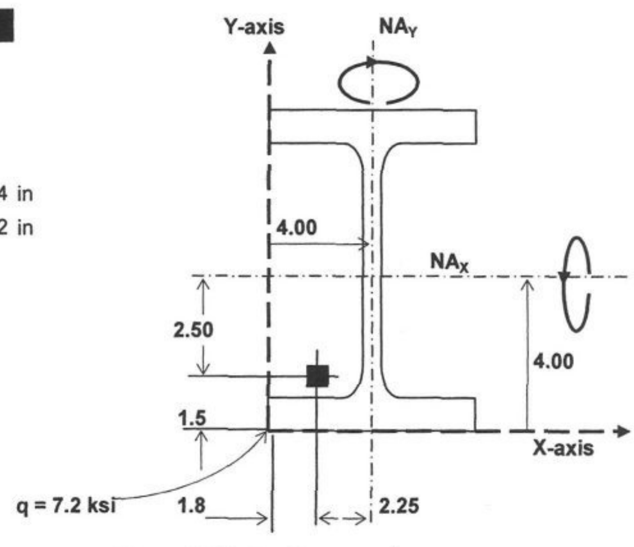


Figure 17-19 Profile measurements.

INPUT FOR P

vert	**1.50**	in↑	Up from X axis
horiz	**1.75**	in→	To right of Y axis
P	**16.2**	kips	
X_arm	-2.25	in→	
Y_arm	-2.5	in	

row 500

Input quadrant for pressure q result

vert	**0.00**	in↑	Up from X axis
horiz	**0.00**	in→	To right of Y axis

$$q \quad P/A \; + \; P\, e_X\, cx\, /\, I_{XX} \; + \; P\, e_Y\, c_Y\, /\, I_{YY} \; = \; \frac{16}{9.1} + \frac{16\ 2.50\ 4.00}{108} + \frac{16\ 2.25\ 4.00}{37}$$

q 1.8 + 1.5 + 3.9 = 7.2 $kips/in^2$ row 510

AutoCAD MASS PROPERTIES

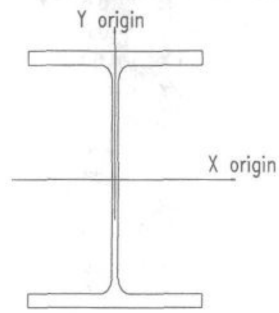
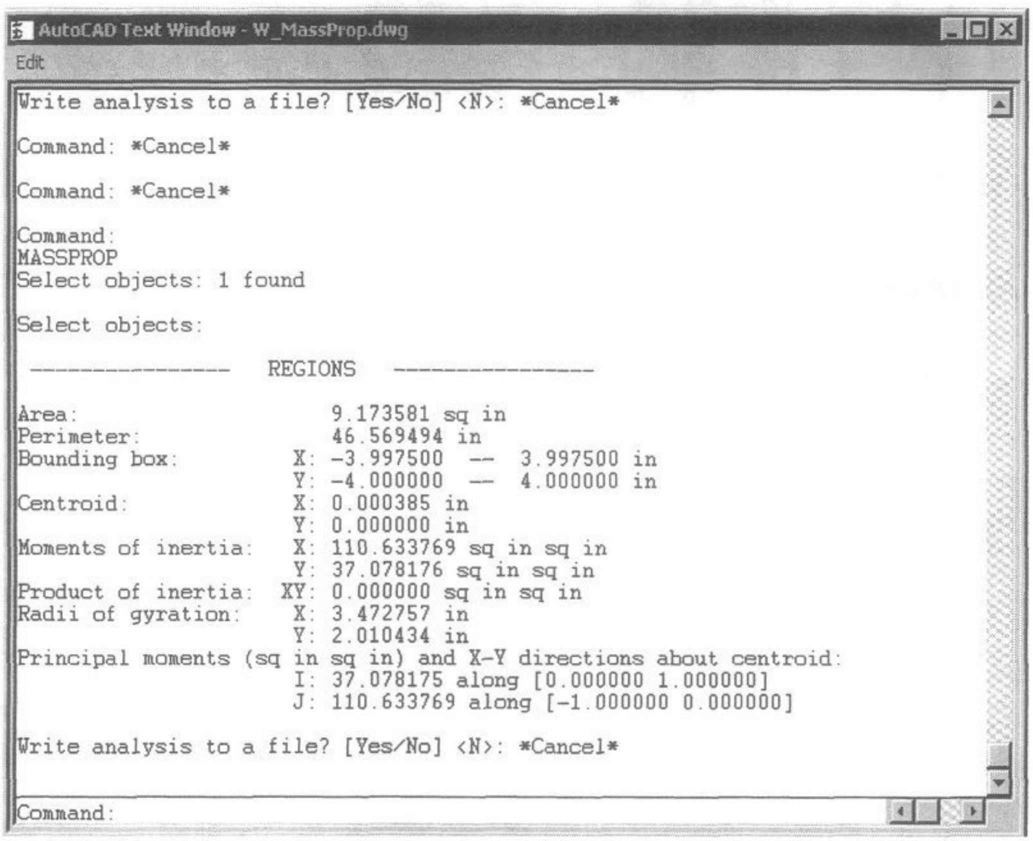


Figure 17-20 The wide-flange profile.

In **AutoCAD**, draw the profile of the shape. When done, this must be a **closed pline**.

Next, use the **region** command and click on the **pline**.

Then, use the **massprop** command to analyze the **region**.



AutoCAD Text Window - W_MassProp.dwg

Edit

```
Write analysis to a file? [Yes/No] <N>: *Cancel*

Command: *Cancel*

Command: *Cancel*

Command:
MASSPROP
Select objects: 1 found

Select objects:

 ----------------    REGIONS    ----------------

Area:                    9.173581 sq in
Perimeter:               46.569494 in
Bounding box:         X: -3.997500  --  3.997500 in
                      Y: -4.000000  --  4.000000 in
Centroid:             X: 0.000385 in
                      Y: 0.000000 in
Moments of inertia:   X: 110.633769 sq in sq in
                      Y: 37.078176 sq in sq in
Product of inertia:  XY: 0.000000 sq in sq in
Radii of gyration:    X: 3.472757 in
                      Y: 2.010434 in
Principal moments (sq in sq in) and X-Y directions about centroid:
                      I: 37.078175 along [0.000000 1.000000]
                      J: 110.633769 along [-1.000000 0.000000]

Write analysis to a file? [Yes/No] <N>: *Cancel*

Command:
```

row 530

row 540

row 550

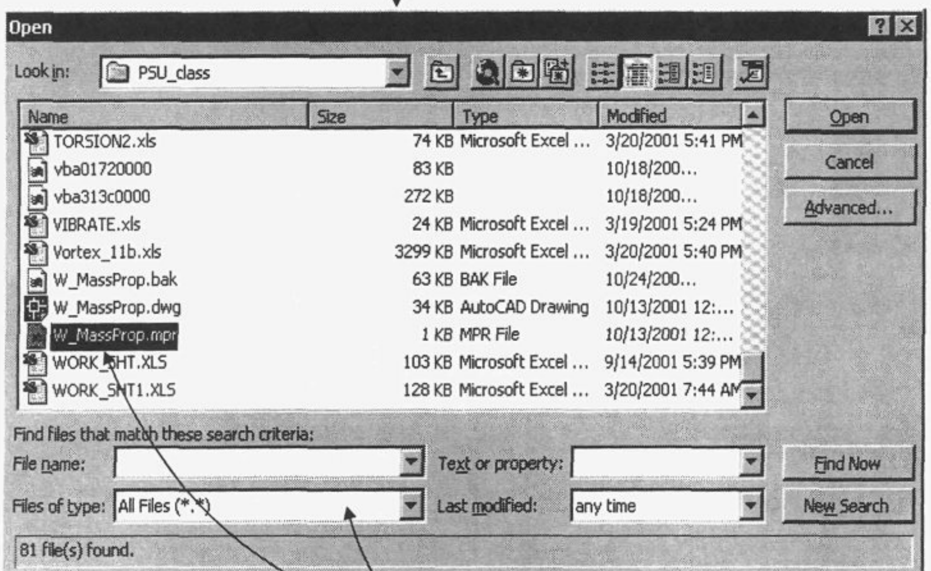
Figure 17-21 The AutoCAD command input window.

You can write the results to an **.mpr** file.

row 560

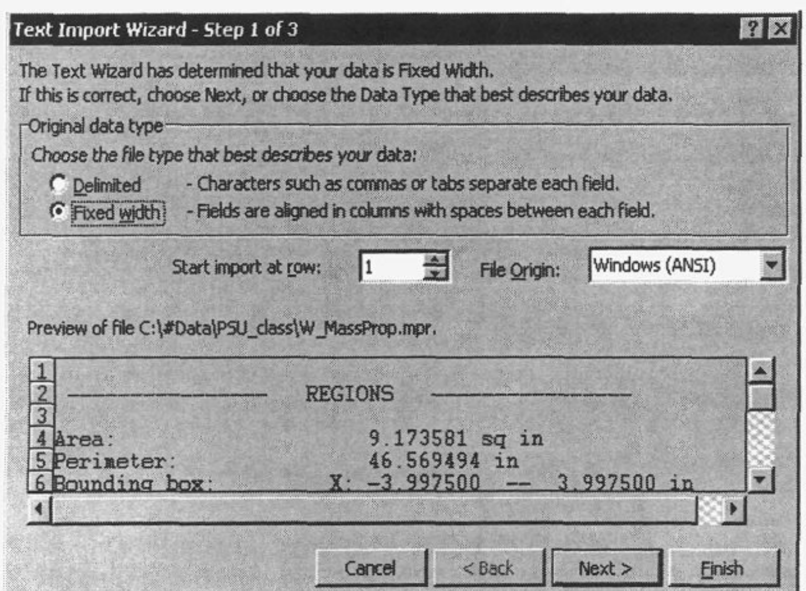
AutoCad MASS PROPERTIES -- Continued

region	AutoCad function -- 2D enclosed area
pline	AutoCAD contiguous line made up of straight line and curves
.mpr	filename extension for an AutoCAD ASCII file
centroid	the point upon which a shape can be balanced



row 580

Figure 17-22 Open the Excel file menu.
Open the file in Excel under the **All Files** option.



row 590

row 600

Figure 17-23 This is the Excel "Text Import Wizard."

row 610

A B C D E F G H I J K L M N O P Q R S T U V W X Y

AutoCad MASS PROPERTIES -- Continued

row 620

row 630

row 640

row 650

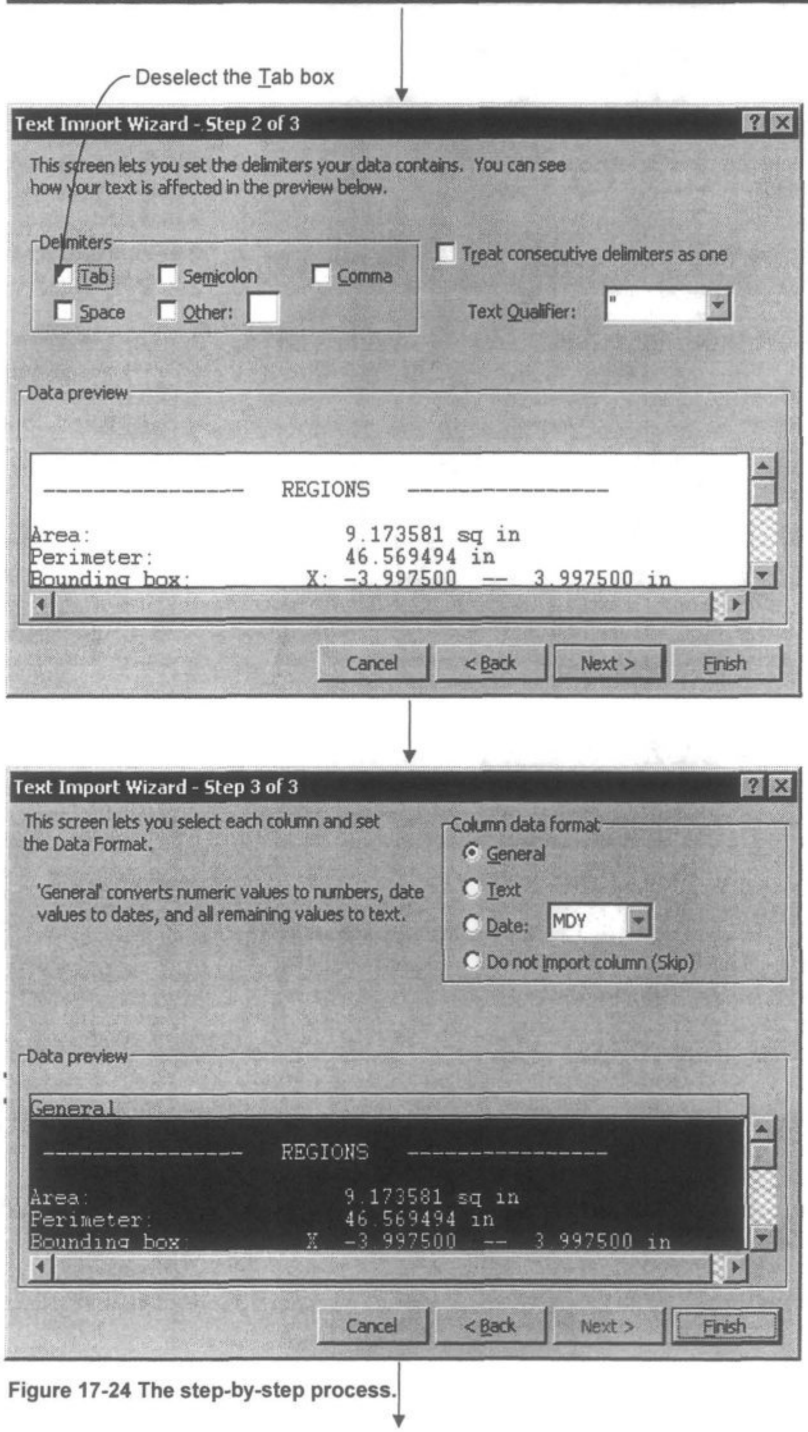
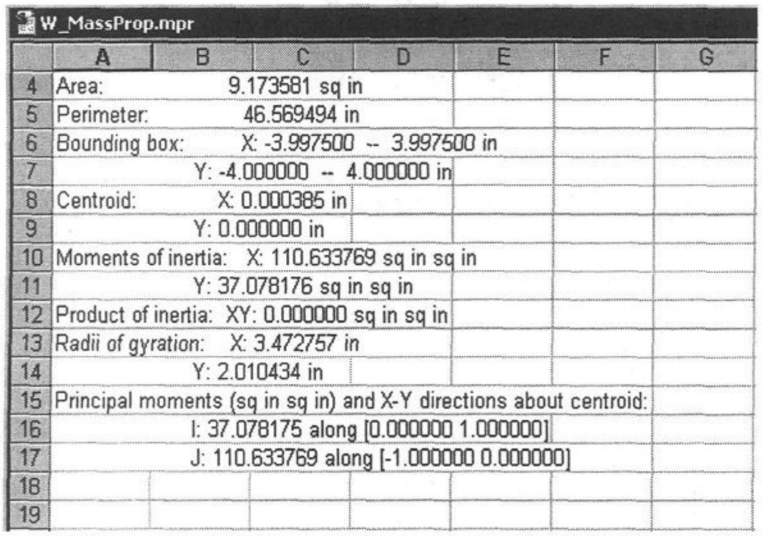


Figure 17-24 The step-by-step process.

row 660

A B C D E F G H I J K L M N O P Q R S T U V W X Y

AutoCad MASS PROPERTIES -- Continued



W_MassProp.mpr

	A	B	C	D	E	F	G
4	Area: 9.173581 sq in						
5	Perimeter: 46.569494 in						
6	Bounding box: X: -3.997500 -- 3.997500 in						
7	Y: -4.000000 -- 4.000000 in						
8	Centroid: X: 0.000385 in						
9	Y: 0.000000 in						
10	Moments of inertia: X: 110.633769 sq in sq in						
11	Y: 37.078176 sq in sq in						
12	Product of inertia: XY: 0.000000 sq in sq in						
13	Radii of gyration: X: 3.472757 in						
14	Y: 2.010434 in						
15	Principal moments (sq in sq in) and X-Y directions about centroid:						
16	I: 37.078175 along [0.000000 1.000000]						
17	J: 110.633769 along [-1.000000 0.000000]						
18							
19							

row 670

row 680

Figure 17-25 Importing text -- this is the resulting spread sheet.

You can save this as an .mpr file or you can
copy clip it into your spread sheet to get this result:

```
 ----------------   REGIONS   ----------------
Area:                        9.173581 sq in
Perimeter:                   46.569494 in
Bounding box:             X: -3.997500  --  3.997500 in
                          Y: -4.000000  --  4.000000 in
Centroid:                 X: 0.000385 in
                          Y: 0.000000 in
Moments of inertia:       X: 110.633769 sq in sq in
                          Y: 37.078176 sq in sq in
Product of inertia:      XY: 0.000000 sq in sq in
Radii of gyration:        X: 3.472757 in
                          Y: 2.010434 in
Principal moments (sq in sq in) and X-Y directions about centroid:
                          I: 37.078175 along [0.000000 1.000000]
                          J: 110.633769 along [-1.000000 0.000000]
```

row 690

row 700

Alternatively, you can copy-clip the AutoCAD text window into your spreadsheet.

If your shape is asymmetrical, do a massprop on the region and check the **Centroid**: values. Move the shape with the move command to the **0, 0** origin of your drawing and do another massprop. If your **Centroid:** reads **0** and **0** then your values for I_{XX} and I_{YY} will be about the neutral axes.

row 710

$$\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\begin{bmatrix}5\\6\end{bmatrix}=\begin{bmatrix}-4.0\\4.5\end{bmatrix}$$

MATRIX MATH

In the Beginning

Solve three equations with three unknowns.

2x + 3y - 1z = -1	line 1
-1x + 5y + 3z = -10	line 2
3x - 1y - 6z = 5	line 3

Eliminate one of the unknowns:

2x + 3y - 1z = -1	* 1 →	2x + 3y - 1z = -1
-1x + 5y + 3z = -10	* 2 →	-2x + 10y + 6z = -20
3x - 1y - 6z = 5		
	add to get:	13y +5z = -21

Get another equation and eliminate **x** again:

2x + 3y - 1z = -1		
-1x + 5y + 3z = -10	* 3 →	-3x + 15y + 9z = -30
3x - 1y - 6z = 5	* 1 →	3x - 1y - 6z = 5
	add to get:	14y + 3z = -25

Combine the two equations with two unknowns:

13y +5z = -21	* 3 →	39y +15z = -63
14y + 3z = -25	* 5 →	70y + 15z = -125
	subtract to get:	31y = -62
	and:	y = -2

Solve for **z**:

13y +5z = -21 →	13 * -2 +5z = -21
	and: z = 1

To get **x**:

2x + 3y - 1z = -1 →	2x + 3 * -2 - 1 * 1 = -1
	to get: x = 3

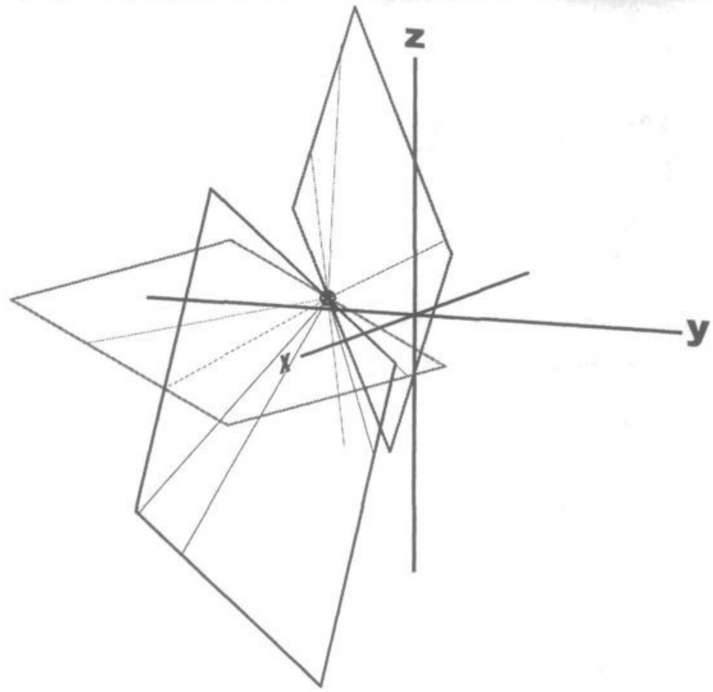


Figure 18-1 The common point of intersecting planes.

These equations each create a family of lines. All of the lines lay within a single plane as determined by that particular equation. The three planes created by the equations intersect at a single, finite point.

The following calculations are used to plot the equations in AutoCad.

-1			
x	y	z	
	-1	-1	
3	**-1**	**-6**	**5**
	1	6	
			-2
		x	**-0.666667**
x	y	z	
-1		-1	
3	-1	-6	5
-3		6	
			2
		y	-2
x	y	z	
-1	-1		
3	-1	-6	5
-3	1		
			7
		z	**-1.166667**

plane 1			plane 2			plane 3		
0.5	x = -0.5	x = -1.5	x = 1.6	x = 10	y = 18	x = -0.67	x = 1.67	y = 4
y = -1	y = 0	y = 1	y = -1	y = 0	y = 1	y = -1	y = 0	y = 1
z = -1	z = 0	z = 1	z = -1	z = 0	z = 1	z = -1	z = 0	z = 1
x = -1	x = 0	x = 1	x = -1	x = 0	x = 1	x = -1	x = 0	x = 1
y = 0	y = -0.33	y = -0.67	y = -1.6	y = -2	y =- 2.4	y = -2	y = -5	y = -8
z = -1	z = 0	z = 1	z = -1	z = 0	z = 1	z = -1	z = 0	z = 1
x = -1	x = 0	x = 1	x = -1	x = 0	x = 1	x = -1	x = 0	x = 1
y = -1	y = 0	y = 1	y = -1	y = 0	y = 1	y = -1	y = 0	y = 1
z = -4	z = 1	z = 6	z = -2	z = -3.33	z = -4.67	z = -1.17	z = -0.8:	z = -0.5

$$\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\begin{bmatrix}5\\6\end{bmatrix}=\begin{bmatrix}-4.0\\4.5\end{bmatrix}$$

A B C D E F G H I J K L M N

MATRIX SOLUTION

Note that the equations take the form of:

	matrix		constants vector
a11	a12	a13	A
a21	a22	a23	B
a31	a32	a33	C

This matrix is of order 3 x 3.

To enter a matrix array: use your cursor to outline an area in the shape of the array you want. Enter a formula such as **=minverse(B89:D91)** and press **[Ctrl] [Shift] [Enter]** all at the same time to get **{=MINVERSE(B89:D97)}** in the array of cells. multiply the invert * constants vector

This matrix is of order 3 x 3.

2	3	-1	-1
-1	5	3	-10
3	-1	-6	5

row 90

The quick solution, as explained below, is:

invert the matrix				constants vector		
0.87097	-0.61290	-0.45161		-1		3 x
-0.09677	0.29032	0.16129	x	-10	=	-2 y
0.45161	-0.35484	-0.41935		5		1 z

A matrix is a rectangular array of numbers which are called elements.
Rows are the first number, columns the second number.
Brackets are sometimes omitted.

row 100

A single row matrix is refereed to as a "row" or vector matrix.
A single column matrix is referred to as a "column" or vector matrix.

Matrices can be multiplied if matrix A has the same number of rows as matrix B has columns.
Note that: AB ≠ BA   AB = C   BA ≠ C   ABC = (AB)C = A(BC)   A(B + C) = AB + AC

A			B			AB	
1	2	3	2	4	=	15	32
4	5	6	2	5		36	77
			3	6			

1 x 2 + 2 x 2 + 3 x 3 = 15
1 x 4 + 2 x 5 + 3 x 6 = 32
4 x 4 + 5 x 5 + 6 x 6 = 77
4 x 2 + 5 x 2 + 6 x 3 = 36

B		A				BA		
2	4	1	2	3	=	18	24	30
2	5	4	5	6		22	29	36
3	6					27	36	45

2 x 1 + 4 x 4 = 18
2 x 2 + 4 x 5 = 24
2 x 3 + 4 x 6 = 30
2 x 1 + 5 x 4 = 22
2 x 2 + 5 x 5 = 29
2 x 3 + 5 x 6 = 36
3 x 1 + 6 x 4 = 27
3 x 2 + 6 x 5 = 36
3 x 3 + 6 x 6 = 45

A'   the transpose of matrix A

A			A'	
1	2	3	1	4
4	5	6	2	5
			3	6

A^{-1} the invert of matrix A $A^{-1}A = AA^{-1} = I$ unitary matrix

A				A^{-1}				I		
20	4	6		0.063	-0.023	-0.027		1	0	0
4	34	-20	X	-0.023	0.056	0.041	=	0	1	0
6	-20	31		-0.027	0.041	0.064		0	0	1

Square Matrix

1	2	3
4	5	6
7	8	9

row 130

Symetrical Matrix

5	1	2
1	4	6
2	6	3

Note: A' is often denoted as A_ in this manual because the range name for A' appears as A_ in Excel. Another notation for A' is At.

Symetrical Matrix also shown as

5	1	2
	4	6
symetrical		3

row 140

Diagonal Matrix

5	0	0
0	6	0
0	0	7

Unit Matrix

1	0	0
0	1	0
0	0	1

row 150

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \begin{bmatrix} 5 \\ 6 \end{bmatrix} = \begin{bmatrix} -4.0 \\ 4.5 \end{bmatrix}$$

3 x 3 MATRIX -- Circuit Anaylsis, Longhand Matrix Solution

See the chapter Quadratic and Cubic Equations for the 2 x 2 matrix solution of two straight lines.

This example includes the longhand solution as well as Excel's **minverse** and **mmult** functions.

Determine the current flow in each of the three loops.

The typical use for this application is **n** equations with **n** unknowns.

After designating the loop currents, we set up voltage equations around each loop. The current in R_5 is I_1 + I_2 whereas the current in R_6 is I_2 - I_3 when referred to loop 2.

In this model we'll use Maxwell's Method.

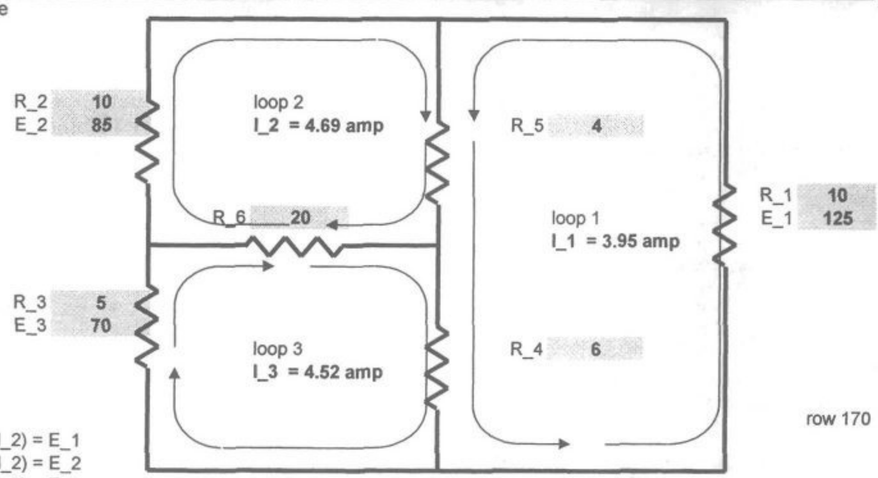


Figure 18-2 Circuit analysis with a 3 x 3 matrix.

row 170

1. R_1 *I_1 + R_5 *(I_1 + I_2) + R4 *(I_1 + I_2) = E_1
2. R_2 *I_2 + R_5 *(I_3 + I_2) + R6 *(I_3 + I_2) = E_2
3. R_3 *I_3 + R_6 *(I_3 + I_2) + R4 *(I_3 + I_1) = E_3

Note: the underbar _ in R_1 is an easy way to show the symbol as a three character variable and makes it easy to create range names with Insert Name Create. Using the symbols R2 or R2, will create range names that are also cell addresses -- not good.

Collect the coefficients of unknowns.

loop 1 (R_1 + R_4 + R_5) *I_1 + R_5 *I_2 + R_4 *I_3 = E_1
loop 2 R_5 *I_1 + (R_2 + R_5 + R_6) *I_2 - R_6 *I_3 = E_2
loop 3 R_4 *I_1 - R_6 *I_2 + (R_3 + R_4 + R_6) *I_3 = E_3 row 180

The cells in a matrix array may contain equations which reference other inputs or equations.

The matrix for these equations is: A

						x	X	=R
	(R_1+R_4+R_5) *I_1	+	R_5 *I_2	+	R_4 *I_3	=	E_1	
	R_5 *I_1	+	(R_2+R_5+R_6) *I_2	+	- R_6 *I_3	=	E_2	
	R_4 *I_1	+	- R_6 *I_2	+	(R_3+R_4+R_6) *I_3	=	E_3	
loop 1	**20** ohms	+	**4** ohms	+	**6** ohms	=	**125** volts	
loop 2	**4**	+	**34**	+	**-20**	=	**85**	
loop 3	**6**	+	**-20**	+	**31**	=	**70**	row 190

Laplace expansion	20	34	-20	4	4	-20	6	4	34	
		-20	31		6	31		6	-20	
+	20	654	–	4	244	+	6	-284		
	13080			976			-1704			
sum	10400 determinant									

Cramer's rule	E	I_2	I_3		I_1	E	I_3		I_1	I_2	E	row 200
	125	4	6		20	125	6		20	4	125	
	85	34	-20		4	85	-20		4	34	85	
	70	-20	31		6	70	31		6	-20	70	
		10400 determinant				10400				10400		
		34	-20			85	-20			34	85	
		-20	31			70	31			-20	70	
+	125	654 = 34 *31 –20 *-20			20	4035			20	4080		
		85	-20			4	-20			4	85	row 210
		70	31			6	31			6	70	
–	4	4035			125	244			4	-230		
		85	34			4	85			4	34	
		70	-20			6	70			6	-20	
+	6	-4080			6	-230			125	-284		
sum I_1	3.95 amps			sum I_2	4.69 amps			sum I_3	4.52 amps			

where 3.95 = (125 *654 - 4 *4,035 +6 *-4,080) / 10,400

row 220

A	B	C	D	E	F	G	H	I	J	K	L	M	N

3 x 3 MATRIX MINVERSE and MMULT Excel Method

1. R_1 *I_1 + R_5 *(I_1 + I_2) + R4 *(I_1 + I_2) E_1
2. R_2 *I_2 + R_5 *(I_3 + I_2) + R6 *(I_3 + I_2) E_2
3. R_3 *I_3 + R_6 *(I_3 + I_2) + R4 *(I_3 + I_1) E_3

Collect the coefficients of unknowns.

loop 1	(R_1 + R_4 + R_5) *I_1 + R_5 *I_2 + R_4 *I_3	E_1
loop 2	R_5 *I_1 + (R_2 + R_5 + R_6) *I_2 - R_6 *I_3	E_2
loop 3	R_4 *I_1 - R_6 *I_2 + (R_3 + R_4 + R_6) *I_3	E_3

row 230

matrix			constants vector	minverse			mmult
20	**4**	**6**	125	0.063	-0.023	-0.027	3.95 amps
4	**34**	**-20**	85	-0.023	0.056	0.041	4.69 amps
6	**-20**	**31**	70	-0.027	0.041	0.064	4.52 amps

4 x 4 MATRIX MODEL Longhand Solution -- not the equation above

x1	**20**	**4**	**6**	**3**	**125**
x2	**4**	**34**	**-20**	**14**	**85**
x3	**6**	**-20**	**31**	**-26**	**70**
x4	**3**	**25**	**9**	**18**	**6**

row 240

Laplace expansion

A	B	C	D	E	F	G	H	I	
	20	34	-20	14					
		-20	31	-26					
		25	9	18					
34	31	-26	-20	-20	-26	14	-20	31	
	9	18		25	18		25	9	
+	34	792	–	-20	290	+	14	-955	row 250
	26928			-5800			-13370		
20	19358	=	387160						
	4	4	-20	14					
		6	31	-26					
		3	9	18					
4	31	-26	-20	6	-26	14	6	31	
	9	18		3	18		3	9	row 260
+	4	792	–	-20	186	+	14	-39	
	3168			-3720			-546		
4	6342	=	25368						
	6	4	34	14					
		6	-20	-26					
		3	25	18					
4	-20	-26	34	6	-26	14	6	-20	
	25	18		3	18		3	25	row 270
+	4	290	–	34	186	+	14	210	
	1160			6324			2940		
6	-2224	=	-13344						
	3	4	34	-20					
		6	-20	31					
		3	25	9					
4	-20	31	34	6	31	-20	6	-20	row 280
	25	9		3	9		3	25	
+	4	-955	–	34	-39	+	-20	210	
	-3820			-1326			-4200		
3	-6694	=	-20082						

sum 368530 determinant

sum 368530 using MDETERM( ) to solve for the determinate of square matrices

row 290

A	B	C	D	E	F	G	H	I	J	K	L	M	N

4 x 4 MATRIX MODEL Longhand Solution -- Continued

Cramer's rule

125	4	6	3	20	125	6	3
85	34	-20	14	4	85	-20	14
70	-20	31	-26	6	70	31	-26
6	25	9	18	3	6	9	18
	368530	determinant			368530		

20	4	125	3	20	4	6	125
4	34	85	14	4	34	-20	85
6	-20	70	-26	6	-20	31	70
3	25	6	18	3	25	9	6
	368530				368530		

A	B	C	D	E	G	H	I	J
		34	-20	14		85	-20	14
		-20	31	-26		70	31	-26
		25	9	18		6	9	18
+	125	19358			20	101856		
		85	-20	14		4	-20	14
		70	31	-26		6	31	-26
		6	9	18		3	9	18
–	4	101856			125	6342		
		85	34	14		4	85	14
		70	-20	-26		6	70	-26
		6	25	18		3	6	18
+	6	2686			6	-12582		
		85	34	-20		4	85	-20
		70	-20	31		6	70	31
		6	25	9		3	6	9
–	3	-133671			3	8571		

sum x1	6.59

sum x2	3.10

B	C	D	E	G	H	I	J
	34	85	14		34	-20	85
	-20	70	-26		-20	31	70
	25	6	18		25	9	6
20	-2686			20	-133671		
	4	85	14		4	-20	85
	6	70	-26		6	31	70
	3	6	18		3	9	6
4	-12582			4	-8571		
	4	34	14		4	34	85
	6	-20	-26		6	-20	70
	3	25	18		3	25	6
125	-2224			6	16286		
	4	34	85		4	34	-20
	6	-20	70		6	-20	31
	3	25	6		3	25	9
3	16286			125	-6694		

sum x3	-0.90

sum x4	-4.63

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \begin{bmatrix} 5 \\ 6 \end{bmatrix} = \begin{bmatrix} -4.0 \\ 4.5 \end{bmatrix}$$

ENGINEERING with the SPREADSHEET

4 x 4 MATRIX MODEL Using MDETERM

A	B	C	D	E	F
x1	20	4	6	3	125
x2	4	34	-20	14	85
x3	6	-20	31	-26	70
x4	3	25	9	18	6

determ *368530*

A	B	C	D	E	F	G	H	I	J	K	L	
34	-20	14	85	-20	14	34	85	14	34	-20	85	
-20	31	-26	70	31	-26	-20	70	-26	-20	31	70	row 370
25	9	18	6	9	18	25	6	18	25	9	6	
125	*19358*	**6.57**	20	*101856*	**5.53**	20	*-2686*	**-0.15**	20	*-133671*	**-7.25**	
85	-20	14	4	-20	14	4	85	14	4	-20	85	
70	31	-26	6	31	-26	6	70	-26	6	31	70	
6	9	18	3	9	18	3	6	18	3	9	6	
4	*101856*	**1.11**	125	*6342*	**2.15**	4	*-12582*	**-0.14**	4	*-8571*	**-0.09**	
85	34	14	4	85	14	4	34	14	4	34	85	
70	-20	-26	6	70	-26	6	-20	-26	6	-20	70	row 380
6	25	18	3	6	18	3	25	18	3	25	6	
6	*2686*	**0.04**	6	*-12582*	**-0.20**	125	*-2224*	**-0.75**	6	*16286*	**0.27**	
85	34	-20	4	85	-20	4	34	85	4	34	-20	
70	-20	31	6	70	31	6	-20	70	6	-20	31	
6	25	9	3	6	9	3	25	6	3	25	9	
3	*-133671*	**-1.09**	3	*8571*	**0.07**	3	*16286*	**0.13**	125	*-6694*	**-2.27**	
		6.59			3.10			-0.90			-4.63	row 390

4 x 4 MATRIX MINVERSE and MMULT Excel Method

						minverse				mmult
20	4	6	3		125	0.0525	0.0039	-0.0030	-0.0161	6.59
4	34	-20	14		85	-0.0172	0.0396	0.0261	0.0097	3.10
6	-20	31	-26		70	-0.0060	-0.0154	0.0139	0.0331	-0.90
3	25	9	18		6	0.0182	-0.0480	-0.0427	0.0282	-4.63

20 year old reference books refer to inverting a matrix as computer intensive. row 400
Now, on a common personal computer, the inversion process is transparent.

row 410

row 420

row 430

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NOTES

ENGINEERING with the SPREADSHEET

A	B	C	D	E	F	G	H	I	J	K	L	M	N

20

30

40

50

60

PART 3:

RETIREMENT HOME EXHAUST STACK

CONSULTING COMPANY

COMMENTS ON CALCULATIONS AND DRAWINGS

Not included on the CD-ROM

ENGINEERING with the SPREADSHEET

A B C D E F G H I J K L M N

COMMENTS

Spiral Binder

Keep a spiral binder. Write down notes on your conversations and phone calls and at what time they occured. Use a date stamp for each day's notes.

Lawyers will tell you that this type of note keeping may be dangerous but, on the other hand, how can you run your life without some sort of record. Remember that your notes and other documents may end up in a hearing or courtroom and write accordingly. You can record personal issues as well. In most jurisdictions, personal notes and notes about other clients can be redacted. Redact items not pertinant to the job by placing a white piece of paper over just the area in question when you are making copies.

No flip or sarcastic comments should occur in your notes, transmittals, drawings, and calculations. This looks bad to your coworkers and will make you look foolish in a hearing.

Calculations

You can inundate a plans examiner with too much information. Pare your calculations and organize them for review. This includes creating a table of contents.

If you are designing several columns, you may want to include a comprehensive calculation for the worst case column and summaries for the others.

Hate Mail

Keep your language polite. Use the term "in my opinion" or "I believe that --" or other terms that don't commit you to making a statement of fact.

For instance, the contractor's registered engineer has stated that some action of yours has caused a serious delay in construction. This professional engineer is, however, lying to cover his/her own shortcommings and you can prove it. Your letter to the owner will include copies of the appropriate documents with a cover letter that states, "It is my opinion that things are not going well for so-and-so and that some of his comments may be a little out-of-line. Please see my documentation."

Don't refer to so-and-so as a dammed liar who blew it. If the problem ends up in a hearing, and you are wrong, you haven't slandered anyone. Also, you have softened your stance leaving a way for the contractor and the engineer to drop his/her position and get on with the project.

Documents

Send drawings and calculations in Adobe .PDF format. The program must be purchased from Adobe. This limits the recipient's ability to alter documents and drawings. http://www.adobe.com

Some authorities recognize Verisign as an electronic signature. This costs about $12/year and applies to only one computer which provides a fair amount of certainty that the documnet was signed by you. http://www.verisign.com

Sometimes a set of of calculations or a spreadsheet template will look good and logical. A few weeks later they may not look good at all. And even if they do, other people may not be able to follow them.

They look good at the moment and sometimes later because you are the one who made them. The information is still in your head or, you're so familiar with certain concepts that you forget that other people may need more explanation.

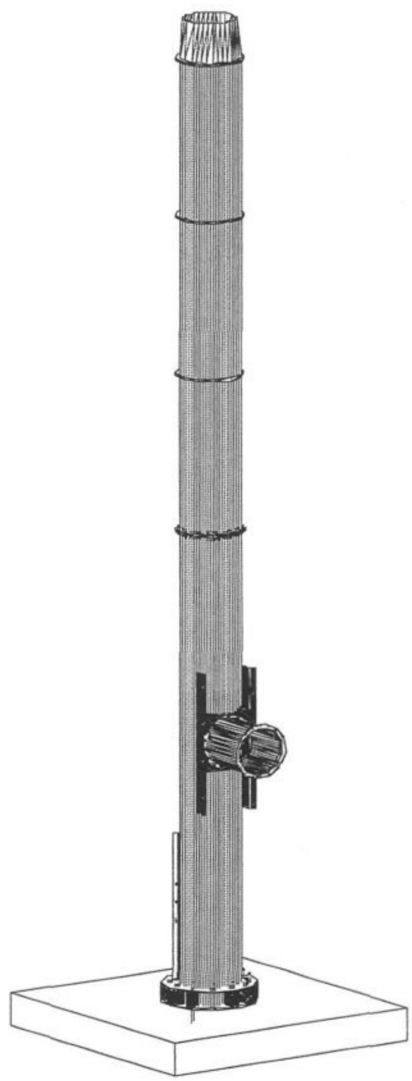
Know your audience and try to address their needs. Put your creation down for a few hours or days and then review it. It will look different and you will want to edit for clarity and accuracy -- this helps others who must also review or rely on your work.

If you don't lie, you'll never have to remember exactly what you said to someone.

STRUCTURAL CALCULATIONS

for

RETIREMENT HOME EXHAUST STACK



Prepared by:
Craig T. Christy, P.E.
July 19, 2002

CONSULTING COMPANY

RETIREMENT HOME EXHAUST STACK

19

19 Exhaust Stack Cover.xls

Christy
12/20/05

ENGINEERING with the SPREADSHEET

TABLE OF CONTENTS

Seismic	Zone 3
Wind	150 mph
Frost	18"
Soil	2000 psf
Corrosion	1/16"

Note: Calculations for vortex shedding are adopted from several sources and give varying answers. These calculations bracket the wind speed at which the stack oscillates and the force of those oscillations.

ENGINEERING with the SPREADSHEET

A	B	C	D	E	F	G	H	I	J	K	L	M	N
SEISMIC CALCULATION WORKSHEET							V = 0.409 W_Ultimate			= 0.292 W_working stress			
Z	0.3	unit	← seismic zone factor		Copy clip **[Ctrl] [c]**,		ZONE	1	2A	2B	3	4	
soil	S_D	←	soil profile type		**[Ctrl] [v]** these values ←		Z	0.075	0.15	0.2	0.3	0.4	
					into the inputs								

Copy clip table values to reduce transcription errors.

Note:
This worksheet operates in a similar manner to the old fashioned checklist. It uses conditional formatting to highlight the results of your inputs from the logic sieves to guide you and provide documentation for the reviewer.

Remove this logo in the upper left corner and replace it with your own.

SOIL PROFILE TYPE		blows/ft	logic	
S_A	Hard rock		0	
S_B	Rock	>50	0	
S_C	Very dense soil & soft rock	15 to 5	0	row 20
S_D	Stiff soil	<15	5	
S_E	Soft soil		0	
S_F	Soil requiring evaluation		0	
			5	

SEISMIC COEFFICIENT C_A UBC TABLE 16 Q

SOIL TYPE	SEISMIC ZONE FACTOR, Z 0.075	0.150	0.200	0.300	0.400
S_A	0.06	0.12	0.16	0.24	0.32
S_B	0.08	0.15	0.20	0.30	0.40
S_C	0.09	0.18	0.24	0.33	0.40
S_D	0.12	0.22	0.28	0.36	0.44
S_E	0.19	0.30	0.34	0.36	0.36
S_F	Soil requiring evaluation				

NOTE: C_a and C_v are no longer used in the IBC or ASCE 7-02 — row 30

C_a	0.36	unitless

C_a — The coefficient that defines the short period ground motion for structures with a fundamental period < C_v /2.5 C_a . — row 40

SEISMIC COEFFICIENT Cv 97 UBC TABLE 16 R

SOIL TYPE	SEISMIC ZONE FACTOR, Z 0.075	0.150	0.200	0.300	0.400	logic	
S_A	0.06	0.12	0.16	0.24	0.32	0	
S_B	0.08	0.15	0.20	0.30	0.40	0	
S_C	0.13	0.25	0.32	0.45	0.56	0	
S_D	0.18	0.32	0.40	0.54	0.64	5	
S_E	0.26	0.50	0.64	0.84	0.96	0	row 50
S_F	Soil requiring evaluation					0	
						5	

C_v	0.54

C_v — The coefficient that defines the longer period constant velocity ground motion.

The first five soil profile types are based upon soil shear wave velocity. Values for **S_F** require a soil specific evaluation to establish site coefficients.

row 60

row 70

A B C D E F G H I J K L M N

NEAR-SOURCE FACTOR Na 97 UBC TABLE 16 S ZONE 4 CALCULATION V = 0.409 W_Ultimate = 0.292 W_working stress

Distance **5** Km 3.11 miles -- Closest distance to known seismic source in Km
type **C** Seismic source type

The Zone 4 calculations are not used in this design but are included in this calculation set for future reference.

The near source factors **N_a** and **N_v** apply to Zone 4 calculations UBC 1628 Symbols and Notations

CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE (Km)

	2.00	5.00	10.00 and greater	
SEISMIC	0	1	1	
SOURCE	1	0	0	
TYPE	0	1	0	
A	1.50	1.20	1.00	1.00
B	1.30	1.00	1.00	1.00
C	1.00	1.00	1.00	1.00

N_a	1.00

SEISMIC SOURCE TYPE 97 UBC TABLE 16 U

A Faults that can produce large magnitude events and have a high rate of activity

B All faults other than A or C

C Faults that are not capable of producing large magnitude events and have a low rate of activity

NOTE: N_a and N_v are no longer used in the IBC or ASCE 7-02

N_a The acceleration based factor for short period structures

row 80
logic
0
0
4
4
choose
5
10
5
hlookup
1
1
5
1

NEAR-SOURCE FACTOR Nv 97 UBC TABLE 16 T ZONE 4 APPLICATION

Distance **5** Km 3.11 miles -- Closest distance to known seismic source in Km
type **C** Seismic source type

row 100

CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE (Km)

	2.00	5.00	10.00	15.00 and greater
SEISMIC	0	1	1	1
SOURCE	1	0	0	0
TYPE	0	1	0	0
A	2.00	1.60	1.20	1.00
B	1.60	1.20	1.00	1.00
C	1.00	1.00	1.00	1.00

N_v	1.00

N_v The velocity based factor for ground motion periods > 1 second

logic
0
0
4
4
choose
5
10
5
hlookup
1
1
5
1

NEAR-SOURCE CALCULATIONS

C_a	**0.36**	unitless	soil type factor 97 UBC Table 16Q
N_a	**1.00**	unitless	near source factor from above
C_a*N_a	0.36	unitless	**C_a*N_a** in Zone 4 UBC 1628 Symbols IF(0.3 zone = 0.4 , 1.00 * 0.36 , 0.36)
C_v	**0.54**	unitless	seismic coefficient 97 UBC Table 16R
N_v	**1.00**	unitless	near source factor from above
C_v*N_v	0.54	unitless	near source factor **N_v** used in Zone 4 IF(0.3 = 0.4 , 0.54 * 1.00Nv , 0.54) see UBC 1628 Symbols and Notations

Check with the local Building Official as to which seismic zone and near source factors may be required.

row 120

Parts of the Oregon coast have been reclassified to Zone 4. More of western Oregon and Washington may be reclassified to Zone 4 in the future.

row 130

A B C D E F G H I J K L M N

SEISMIC CALCULATION WORKSHEET

Z	**0.3**	unitless	zone acceleration factor from above	R	The structure response factor based upon the structure configuration, stiffness, and force amplification characteristics in an earthquake leading to a ratio of seismic base shear to the ability of the structure to absorb energy and inelastic deformations without collapse.
soil	**SD**	alpha	soil type Stiff soil		
R	**2.2**	unitless	**Tanks, vessels or pressurized spheres on braced or unbraced legs**		
			Highlight callouts that change frequently		Note that the structure may be rendered useless by the seismic event that it was designed for under this system. However, some designs account for inelastic deformations and the continued use of the structure with or without repairs.
I	**1**	unitless	importance factor		
h_n	**75**	ft	building height		
C_t	**0.020**	unitless	building period factor based upon construction style 97 UBC 1630.2.2	I	importance factor
T	0.510	seconds	Ct * hn^0.75 . (30-8) natural period .. 0.020 * (75.0^0.75)	T > 0.06	Flexible nonbuilding structure .. use UBC 1630.5 V = Ft + sum Fi .. row 150
V rigid	0.252	* W	0.7 * C_a * I * W (34-1) 0.7 * 0.36 * 1.00 * W	V	lateral force, * W
V flexible	0.482	*W	C_v * I / (R * T) *W (30-4) 0.54 * 1.00 / (2.2 * 0.510) * W		
V	0.482	*W	flexible structure ..		

row 160

Vmax	0.409	*W	2.5 * C_a * I / R * W (30-5) 2.5 * 0.36 * 1.00 / 2.2 * W	maximium lateral force
Vmin	0.040	*W	0.11 * C_a * I * W (30-6) 0.11 * 0.36 * 1.00 * W	this value sets the lower bounds for long period structures $\mathbf{C_a}$ is multplied by $\mathbf{N_a}$ in Zone 4 calculations

Write out the actual equation

This concatenated string displays the actual values used

Structure	**1**	input	**0** = building structure 0.8 in (30-7), **1** = non building structure 1.6 in (34-3)	row 170
Vmin_4a	0.202	*W	0.56 * C_a * I * W (34-2) 0.56 * 0.36 * 1.00 * W	for non-building structures $\mathbf{C_a}$ is multplied by $\mathbf{N_a}$ in Zone 4 calculations
	1	logic	for flexible nonbuilding structures 1634.5	
N_v	1.00	unitless	near source factor for Zone 4 calculations	
Vmin_4b	0.218	*W	0.8 in (30-7), 1.6 in (34-3) * Z * N_v * I / R * W (34-3) 1.6 * 0.30 * 1.00 * 1.00 / 2.2 * W	row 180
zone	0	logic	0.3 = 0.4 is not Zone 4 ..	
V_applied$_u$	**0.409**	*W_ultimate strength	T > 0.06 Flexible nonbuilding structure ..	
V_applied$_w$	**0.292**	*W_working stress	T > 0.06 Flexible nonbuilding structure ..	

Highlight the results in a way that will be eye catching in print. It also helps to include your hand checking in the white space (areas free of print)

row 190

A B C D E F G H I J K L M N

UBC 1634 Non-Building Structures at Grade V = 0.409 W_Ultimate = 0.292 W_working stress

V **0.292** *W applied

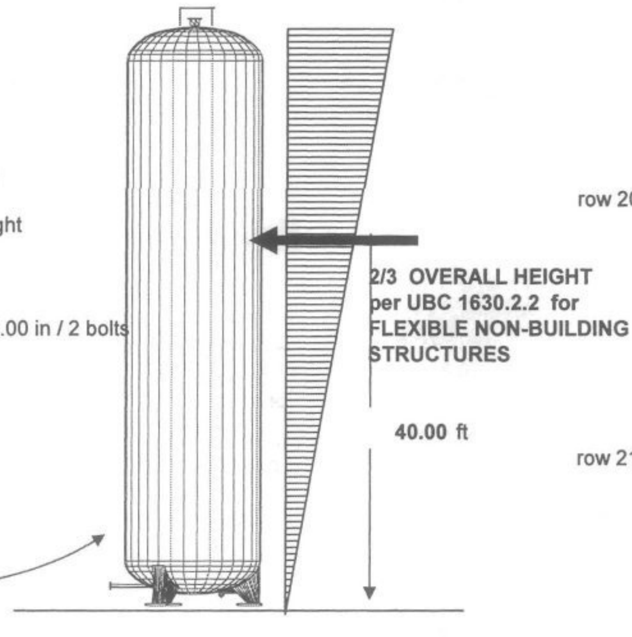
For nonbuilding structures at / or below grade

weight	**60000**	lbs	gross weight of item
CG	**480**	in	mass center of gravity
M_ot	8415584	in-lbs	0.292 g * 480.00" * 60,000 lbs
bolt_brg	**90**	in	bolt to bearing to resist overturning
CG_rt	**30.00**	in	arm in plan view to cg of gross weight
M_rt	1530000	in-lbs	0.85 * 60,000 lbs* 30.00 in
Bolts t	**2**		
tension	38253	lbs	(8,415,584 - 1,530,000) in-lbs / 90.00 in / 2 bolts
Bolts v	**4**		
shear	4383	lbs	0.292 * 60,000 lbs / 4 bolts

row 200

For initial estimate of forces on anchor bolts and foundation.

row 210



Use a diagram, picture, or drawing to explain something that may not be readily apparent

In this case, most designers don't realize that a large, three legged tank is a flexible structure

Figure 20-1 FLEXIBLE STRUCTURE

row 220

row 230

row 240

row 250

ENGINEERING with the SPREADSHEET

21 Wind.xls

A B C D E F G H I J K L M N

WIND '97 UBC

V_basic	**36**	mph	basic wind speed **per customer specifications**
Exposure	**B**	2	Exposure and gust factor coefficient B or C 16-G
I	**1**	unitless	importance factor 16-K
C_q	**0.80**	unitless	pressure coefficient from Table 16-H
h_slab	**2.00**	ft	from grade to foundation interface to top of foundation

$P = C_e * C_q * q_s * I$

16-F q_s WIND STAGNATION PRESSURE at STANDARD HEIGHT of 33'

row 20

Speed mph	70.0	80.0	90.0	100.0	110.0	120.0	130.0	**150.0**	**175.0**	basic wind speed
q_s psf	12.6	16.4	20.8	25.6	31.0	36.9	43.3	57.6	78.4	0.00256 * basic_wind_speed^2 mph

q_s 3.3 psf wind stagnation pressure, std ht 33', 16-G

16-K OCCUPANCY CATEGORY

	I_E	I_Ep	I_Wind
1. ESSENTIAL FACILITIES	**1.25**	**1.5**	**1.15**
2. HAZARDOUS FACILITIES	**1.25**	**1.5**	**1.15**
3. SPECIAL OCCUPANCY	**1.0**	**1.0**	**1.0**
4. STANDARD OCCUPANCY	**1.0**	**1.0**	**1.0**
5. GROUP U	**1.0**	**1.0**	**1.0**

Hydrogen, oxygen, nitrogen, and carbon dioxide all qualify as hazardous materials. This requires a higher importance factor.

16-H Cq PRESSURE COEFFICIENTS
Chimneys, tanks, solid towers

Square or Rectangular	**1.4**
Hexagonal or octagonal	**1.1**
Round or elliptical	**0.8**

16-G Ce COMBINED HEIGHT, EXPOSURE, and GUST FACTOR COEFFICIENT

HEIGHT	Exp_D	Exp_C	Exp_B	w/o C_q	with C_q
400	2.34	2.19	1.80	6.0	4.8
300	2.23	2.05	1.63	5.4	4.3
200	2.10	1.87	1.42	4.7	3.8
160	2.02	1.79	1.31	4.4	3.5
120	1.93	1.67	1.20	4.0	3.2
100	1.88	1.61	1.13	3.8	3.0
80	1.81	1.53	1.04	3.5	2.8
60	1.73	1.43	0.95	3.2	2.5
40	1.62	1.31	0.84	2.8	2.2
30	1.54	1.23	0.76	2.5	2.0
25	1.50	1.19	0.72	2.4	1.9
20	1.45	1.13	0.67	2.2	1.8
15	1.39	1.06	0.62	2.1	1.7

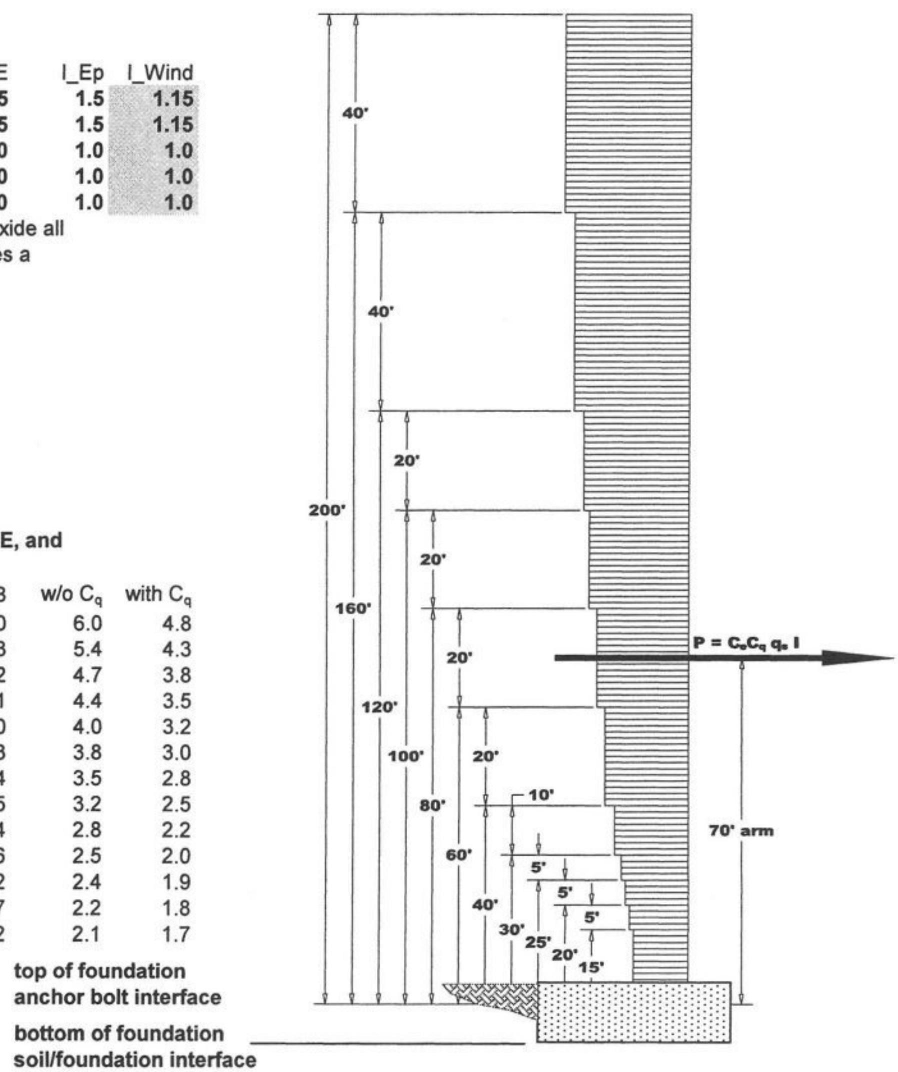


Figure 21-1 Graduated wind force acting on a structure.

row 70

A B C D E F G H I J K L M N

WIND OVERTURNING -- INCREMENTAL MOMENTS

Heights are taken from the top of the footing

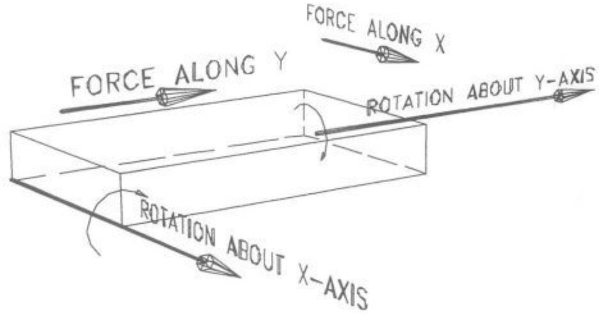
		ABOUT X-Axis ↑			To the TOP of the footing ↑			To the BOTTOM of the footing ↑		
		ht 1	ht 2	width	force	arm	Mot	arm	Mot	
HEIGHT	q psf	from bot	to top	along X	about x	about x	about x	about x	about x	
400	4.8	**300**	**400**	**0**	0.00	350.00	0.0	352.00	0.0	
300	4.3	**200**	**300**	**0**	0.00	250.00	0.0	252.00	0.0	
200	3.8	**160**	**200**	**0**	0.00	180.00	0.0	182.00	0.0	
160	3.5	**120**	**160**	**0**	0.00	140.00	0.0	142.00	0.0	
120	*3.2*	***100***	***120***	***0***	*0.00*	*110.00*	*0.0*	*112.00*	*0.0*	*row 80*
100	3.0	**80**	**100**	**0**	0.00	90.00	0.0	92.00	0.0	
80	2.8	**60**	**80**	**3.5**	0.19	70.00	13.6	72.00	14.0	
60	2.5	**40**	**60**	**3.5**	0.18	50.00	8.9	52.00	9.2	
40	2.2	**30**	**40**	**3.5**	0.08	35.00	2.7	37.00	2.9	
30	2.0	**25**	**30**	**3.5**	0.04	27.50	1.0	29.50	1.0	
25	1.9	**20**	**25**	**3.5**	0.03	22.50	0.8	24.50	0.8	
20	1.8	**15**	**20**	**3.5**	0.03	17.50	0.5	19.50	0.6	
15	1.7	**0**	**15**	**3.5**	0.09	7.50	0.7	9.50	0.8	

0.64 k **28.1 k-ft top** row 90
1376.00 **29.4 k-ft bottom**

		ABOUT Y-Axis →			To the TOP of the footing →			To the BOTTOM of the footing →		
		ht 1	ht 2	width	force	arm	Mot	arm	Mot	
HEIGHT	q psf	from bot	to top	along X	about x	about x	about x	about x	about x	
400	4.8	**300**	**400**	**0**	0.00	350.00	0.0	352.00	0.0	
300	4.3	**200**	**300**	**0**	0.00	250.00	0.0	252.00	0.0	
200	3.8	**160**	**200**	**0**	0.00	180.00	0.0	182.00	0.0	
160	3.5	**120**	**160**	**0**	0.00	140.00	0.0	142.00	0.0	row 100
120	3.2	**100**	**120**	**0**	0.00	110.00	0.0	112.00	0.0	
100	3.0	**80**	**100**	**0**	0.00	90.00	0.0	92.00	0.0	
80	2.8	**60**	**80**	**3.5**	0.19	70.00	13.6	72.00	14.0	
60	2.5	**40**	**60**	**3.5**	0.18	50.00	8.9	52.00	9.2	
40	2.2	**30**	**40**	**3.5**	0.08	35.00	2.7	37.00	2.9	
30	2.0	**25**	**30**	**3.5**	0.04	27.50	1.0	29.50	1.0	
25	1.9	**20**	**25**	**3.5**	0.03	22.50	0.8	24.50	0.8	
20	1.8	**15**	**20**	**3.5**	0.03	17.50	0.5	19.50	0.6	
15	1.7	**0**	**15**	**3.5**	0.09	7.50	0.7	9.50	0.8	

row 110

0.64 k **28.1 k-ft top**
1376.00 **29.4 k-ft bottom**



row 120

Figure 21-2 FOUNDATION SIGNS

row 130

VERIFICATION OF TABLE VALUES

Determine if published coefficients of C_e create a smooth line and if these values can generate a formula.

Published Table Values

Gust Factor Coefficient C_e

HEIGHT	Exp_D	Exp_C	Exp_B
400	2.34	2.19	1.80
300	2.23	2.05	1.63
200	2.10	1.87	1.42
160	2.02	1.79	1.31
120	1.93	1.67	1.20
100	1.88	1.61	1.13
80	1.81	1.53	1.04
60	1.73	1.43	0.95
40	1.62	1.31	0.84
30	1.54	1.23	0.76
25	1.50	1.19	0.72
20	1.45	1.13	0.67
15	1.39	1.06	0.62

$y = 0.8987x^{0.1597}$ $R^2 0.9998 =$

$y = 0.5824x^{0.2206}$ $R^2 0.9998 =$

$y = 0.252x^{0.3262}$ $R^2 0.9995 =$

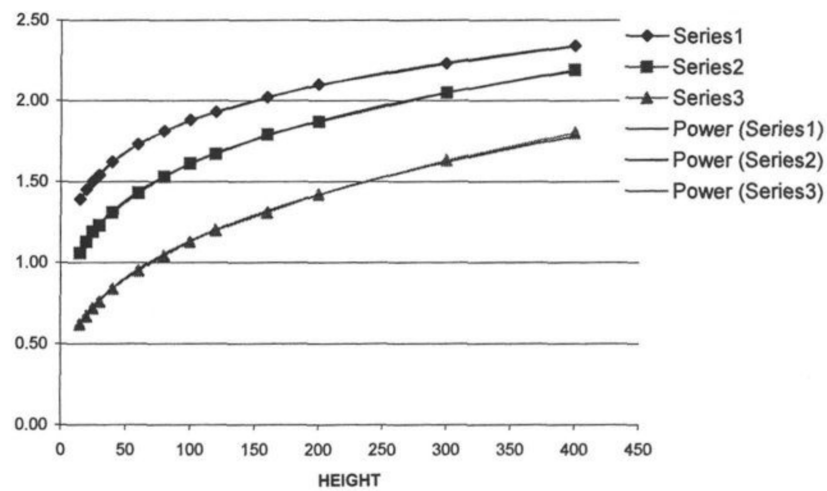


Figure 21-3 TABLE VALUES

Calculation: Wind Pressure versus Velocity

V	**35.6**	mph	
P wind	3.3	lb/ft^2	0.00257 * (V miles/hour)^2

C_e	Gust Factor Coefficient
C_q	*pressure coefficient*
V wind	velocity of wind, miles/hour
P wind	pressure of wind, Lbs./ft²
Q_s	wind stagnation pressure at standard height
q_s	wind pressure at a designated height, Lbs./ft²
I	importance factor
V_basic	basic wind speed, miles/hour
Exposure	Exposure and gust factor coefficient B, C, or D

row 170

row 180

row 190

CONSULTING COMPANY

VORTEX SHEDDING INTRODUCTION
EXHAUST STACK

22

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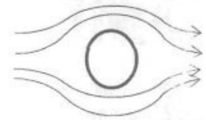


Not included on the CD-ROM

ENGINEERING with the SPREADSHEET

22 Vortex Intro.xls

A B C D E F G H I J K L M N

VORTEX SHEDDING INTRODUCTION

weight 485 lb/ft^3 weight of steel

s	stress, ksi
e	coefficient of expansion, unitless
E	Young's modulus of elasticity, ksi
Fy	first yield strength, ksi

Coefficient of expansion e
6.5E-06 unitless at 70 to 100 degrees Fahrenheit
6.50E-06
$(6.1 + 0.0019 * t) \times 10^{-6}$
at 200 to 1200 degrees F where t = temperature

t **500** deg F
e 7.05E-06

Modulus of elasticity E for carbon steels with C < 0.30%

	29000	ksi	at 70 degrees F
	22400	ksi	at 900 degrees F -- varies linearly and drops off rapidly after 900 degrees F
E heat	**26099**	ksi	at 500 degrees F

F_y is generally constant from -20 to 650 degrees F

Suggested Damping

5 %	concrete chimneys	input as:	0.05
3 to 5 %	lined steel stacks		0.03 to 0.05
1 to 2 %	unlined steel stacks		0.01 to 0.02

Table 1 -- PLATE VALUES
Plate used in fabrication of vessels

per API 620 2002 Table R-4 and 2.2.3.2 ASTM Specifications

	F_y yeild ksi	F_t tensile, ksi	allowable tensile, ksi
A36 modification 2 manganese content to have a range of 0.80 to 1.20% Material shall not be rimmed or capped steel	36	58	16.0
A131 structural quality only	34	58	14.0
A283 grade C maximimum thickness of 3/4"	30	55	14.0
A283 grade D maximum thickness of 3/4"	33	60	14.0
A285 grade C only maximum thickness of 3/4"	30	55	16.5
A442	30	55	16.5
A516 grade 55modification 1 max carbon content 0.20%, max manganes content of 1.50%	32	60	18.0
A516 modification 2 max carbon content 0.20%, max manganese content of 0.70 to 1.40%, max silicon 0.50%, steel shall be normalized			
A537 carbon 0.20%, manganese 0.85 to 1.60%, max thickness 1 1/2"	50	70	21.0
A573 grade 58	32	58	16.0
A633 grades C and D	50	70	17.8
A662 grade B	40	65	19.5
A662 grade C	43	70	21.0
A678 grade A max thickness 1 1/2"	50	70	17.8
A678 grade B max thickness 2 1/2"	60	80	20.3
A737 grade B max thickness 2 1/2"	50	70	21.0

Where API note 4 includes a 0.92 quality factor for plate used as structural material.
Use 20 plf additional weight for ladders and stiffeners.

VORTEX SHEDDING INTRODUCTION
EXHAUST STACK

Not included on the CD-ROM

Reference

PRESSURE VESSEL DESIGN HANDBOOK
Copyright 1986 reprinted 1991
Krieger Publishing 2nd ed. **PVDH**

GUIDE FOR STEEL STACK DESIGN AND CONSTRUCTION
Sheet Metal and Air Conditioning Contractors' National Association Inc.
SMACNA 1996 http://www.smacna.org

DESIGN of PROCESS EQUIPMENT
Pressure Vessel Handbook Publishing, Inc.
Kanti K. Mahajan 1990 **DPE**

DESIGN and CONSTRUCTION of LARGE, WELDED, LOW-PRESSURE STORAGE TANKS
API Standard 620, Tenth Edition, February 2002
American Petroleum Institute **API**

Formulas for Stress and Strain
Fifth Edition
Raymond J. Roark, Warren C. Young
McGraw-Hill Book Company

Before you design a tall stack or process vessel, you must secure your own references.

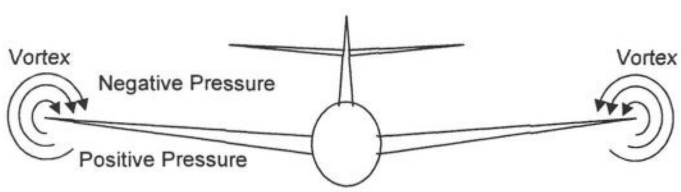
With the assistance of this template, you will need two to five days to design a stack with a critical aspect ratio. This time includes your learning curve. This estimate may be optimistic.

If you breeze through this process you risk leaving 10,000 to 20,000 lbs of material on the ground.

Stacks typically fail at 15 to 30 mph of wind which provides a steady-state flow so that the stack can vibrate like a reed in the wind. Winds above 60 mph usually blow as gusts.

The different references in this template reflect different philosophies, research, and experience. No reference will generate an exact, guaranteed answer. The best approach is to bracket your answers. The calculations in this template will provide comparisons, where to look in your references, and some assurance that your design is reasonable.

In designing anchor bolts and bolt rings, a conservative, shotgun approach saves design time by using more concrete and steel. This is an economical trade-off. The body of the stack, however, is a different matter. Design with care.



This is the type of vortex that most of us are familiar with.

Figure 22-1 Vortex created at aircraft wingtips.

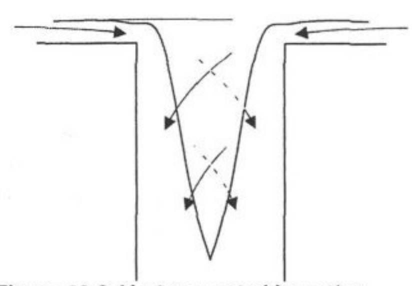


Figure 22-2 Vortex created by water down the drain.

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VORTEX SHEDDING IN TALL STACKS AND VESSELS

EXHAUST STACK

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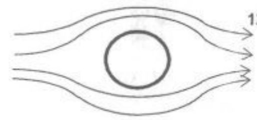


ENGINEERING with the SPREADSHEET

23 Vortex Shedding.xls

A B C D E F G H I J K L M N

SUMMARY

Wind	**150**	mph	per the customer
Seismic	**0.511**	g_ult	zone 3, importance factor 1.25 E/ 1.15 W, R 2.2, C_a 0.36
	0.365	g_working	
soil	**2000**	psf	estimated
L	**62.5**	ft	height of stack/structure from TANK inputs
D	**3.500**	ft	max stack diameter at CL of plate
E	**26099**	ksi	modulus of elasticity at operating temperature
corrosion	**1/16**	inch	corrosion allowance per ICE and NTS
t	**500**	deg F	
e	7.05E-06		coefficient of expansion, unitless
E heat	**26099**	ksi	at 500 degrees F

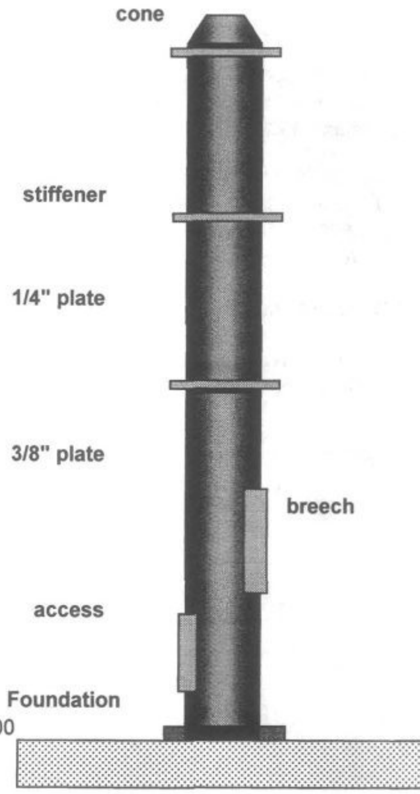


Figure 23-1 ELEVATION VIEW

row 20

row 30

row 40

row 50

Results Following PVDH Guidelines

W	6.944	k	gross weight of structure

Using method of superposition and incremental moments

M wind	**344.7**	k-ft	
d wind	**4.27**	in	
M seismic	**124.3**	k-ft wk'g	
d seismic	**1.22**	inch	
T_n	**0.334**	cycles/sec	natural, resonant frequency of structure
f_n	2.991	Hz	1 /T_n frequency
V_wind	**15.0**	mph	possible vortex sheding wind speed where R_e < 50,000
V_wind	**35.6**	mph	vortex shedding per resonant frequency of structure
M_res1	**536.1**	k-ft	vortex induced moment at 35.6 mph and foundation magnification factor of 60 at 1 ft above base / top of bolting ring **USE THIS MOMENT IN DESIGN**

Results Following DPE Guidelines

W_s	**5.208**	k	corroded weight of stack
K_1'	**0.136**	unitless	ratio of force to structure weight
K_1''	**13.320**	unitless	ratio of force to structure weight and modulus
			13.320 > 1/15 CHECK CANTILEVER VIBRATION
$D_{cantilever}$	**2.03**	inch	amplified deflection
M vortex	**165.0**	k-ft	vortex induced moment

row 60

Ovaling

f_n	**4.33**	cycle/sec	SMACNA
f oval	**13.66**	cycle/sec	PVDH
fr_oval	**10.29**	cycle/sec	DPE

http://www.smacna.org

row 70

VORTEX SHEDDING IN TALL STACKS AND VESSELS
EXHAUST STACK

23 Vortex Shedding.xls

A	B	C	D	E	F	G	H	I	J	K	L	M	N

TANK / STACK DESIGN PVDH

L	62.5 ft	height of stack/structure from TANK inputs PVDH pg 120
D	3.500 ft	max stack diameter at CL of plate
E	29500 ksi	modulus of elasticity
Aspect	17.9 !!!	L/D for unlined steel stack <= 13 vibrational analysis not required L/D for lined steel stack <= 15 vibrational analysis not required L/D for process columns <= 15 vibrational analysis not required
W_{DL+LL}	6.944 k	estimated total weight -- this value used in calculations
factor	9.1 !!!.	$W / (h * D^2) * 1000$ $W / (h * D^2) <= 20$ vibration analysis MUST be performed $20 < W / (h * D^2) <= 25$ vibration analysis SHOULD BE PERFORMED $25 < W / (h * D^2) * 1000$ vibration analysis NEED NOT be performed
$W_{DL\ only}$	6.944 k	
	9.1 !!!.	
corrosion	0.063 inch	corrosion allowance

row 80

row 90

METHOD OF SUPERPOSITION FOR WIND DEFLECTION PVDH PAGE 103

unit wt 0.111 k/ft for reference

	ht 1 from bot	ht 2 to top	width ft	t_PL inch	wind psf	sum k	running sum k	M_Wind k-ft
k	120	150	0	0	0.0	0.000	0.000	0.0
j	100	120	0	0	0.0	0.000	0.000	0.0
i	80	100	0	0	0.0	0.000	0.000	0.0
h	60	80	0	0	0.0	0.000	0.000	0.0
g	40	62.5	3.5	0.25	54.9	4.326	4.326	221.7
f	30	40	3.5	0.25	48.6	1.700	6.026	59.5
e	25	30	3.5	0.375	43.9	0.769	6.795	21.1
d	20	25	3.5	0.375	41.6	0.729	7.524	16.4
c	15	20	3.5	0.375	38.7	0.678	8.202	11.9
b	1	15	3.5	0.375	35.9	1.757	9.958	14.1
a	0	1	3.5	0.375	35.9	0.125	10.084	0.1
						10.084		**345 k-ft working**

row 100

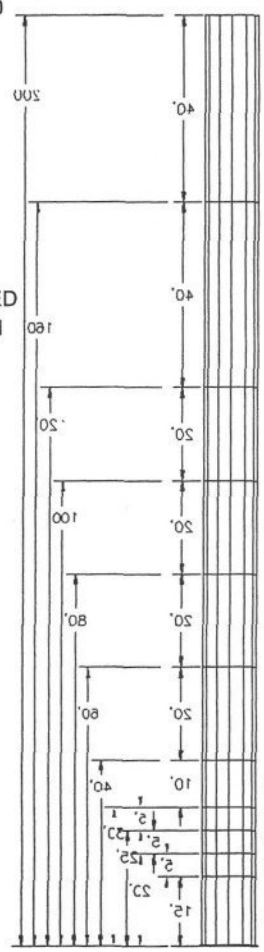


Figure 23-2 ELEVATION VIEW

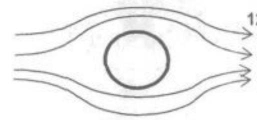
WIND Incremental Moments

Wind 150 mph maximum wind speed

	ft	k-ft	k-ft	k-ft	k-ft	k-ft	k-ft	k-ft	k-ft				sum row k-ft
k	0	0.0											0.0
j	0	0.0	0.0										0.0
i	0	0.0	0.0	0.0									0.0
h	0	0.0	0.0	0.0	0.0								0.0
g	22.5	48.7	0.0	0.0	0.0	0.0							48.7
f	10	8.5	91.9	0.0	0.0	0.0	0.0						100.4
e	5	1.9	17.0	113.6	0.0	0.0	0.0	0.0					132.5
d	5	1.8	5.8	25.5	135.2	0.0	0.0	0.0	0.0				168.3
c	5	1.7	5.5	9.6	34.0	156.8	0.0	0.0	0.0	0			207.6
b	14	12.3	11.2	15.7	20.4	57.8	161.1	0.0	0.0	0	0		278.5
a at base	1	0.1	14.1	11.9	16.4	21.1	61.2	221.7	0.0	0	0	0	**346.4**
footing	2.00	0	0.2	17.6	13.2	17.9	21.1	62.9	230.4	0	0	0	**363.2**
													k-ft

L structure 62.5 ft

row 130



23 Vortex Shedding.xls

WIND Lateral Deflections

A	B	C	D	E	F	G	H	I	J	K	L	M	N
	corrosion			segment² y_incr				delta			theta	theta	
	allowance	Area	I	EI	d_W	d_Q	d_M	sum 1		theta W	Q	M	sum 2
	inch	ft²	ft⁴	1 /k	ft	ft	ft		1 /k	ft	ft	ft	
k	0.0625	0.00	0.00	0	0.0000	0.0000	0.0000	0.000	0	0	0	0	0
j	0.0625	0.00	0.00	0	0.0000	0.0000	0.0000	0.000	0	0	0.00	0	0
i	0.0625	0.00	0.00	0	0.0000	0.0000	0.0000	0.000	0	0	0.00	0	0
h	0.0625	0.00	0.00	0	0.0000	0.0000	0.0000	0.000	0	0	0.00	0	0
g	0.0625	0.17	0.26	0.000453	0.0055	0.0147	0.0110	0.031	0.000453	0.007	0.01	0.022	0.04355
f	0.0625	0.17	0.26	8.95E-05	0.0002	0.0018	0.0045	0.006	0.000291	8E-04	0.00	0.029	0.03306
e	0.0625	0.29	0.44	1.34E-05	0.0000	0.0002	0.0009	0.001	0.000101	6E-05	0.00	0.013	0.01534
d	0.0625	0.29	0.44	1.34E-05	0.0000	0.0002	0.0011	0.001	0.000114	7E-05	0.00	0.019	0.02167
c	0.0625	0.29	0.44	1.34E-05	0.0000	0.0002	0.0014	0.002	0.000128	7E-05	0.01	0.026	0.03602
b	0.0625	0.29	0.44	0.000105	0.0003	0.0049	0.0147	0.020	0.000462	0.002	0.00	0.129	0.13296
a	0.0625	0.29	0.44	5.37E-07	0.0000	0.0000	0.0001	0.000	3.36E-05	7E-07	0.00	0.012	0.01163
								0.062 ft				sum 2	0.29423

I used in the following calculations

sum 1 + sum 2 **0.36 ft**
4.27 in

METHOD OF SUPERPOSITION for SEISMIC DEFLECTION PVDH pg 103

Seismic	0.511	g_ultimate	
$E_{\_ASD}$	0.365	g_working	Seismic /1.4
t	0.1875	in	corroded plate thickness
$W_{DL+LL\_}$	6.944	k	estimated total weight from above -- this value used in calculations
w	0.111	k/ft	W_{DL+LL} / height — estimated natural period
T_n	0.380	sec/cycle	0.00000765 * (Height /d)^2 * (w * d /t)^0.5 DPE value
V	2.5	k	$E_{\_ASD}$ * W_{DL+LL}
	0.041	k/ft	V /L
F_t	0.1	k	0.07 * T_n * V F_t < = 0.25 V
F	2.5	k	V - F_t
	0.039	k/ft	F /L

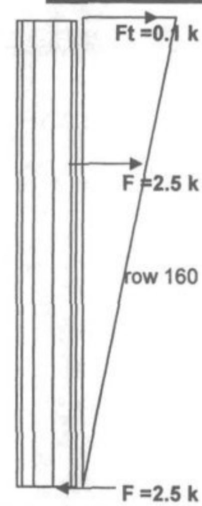


Figure 23-3 SEISMIC LOADING

	ht 1 from bot	ht 2 to top	mean width ft	t_PL inch corroded	Seismic mass w k	wh k-ft	wh/sum wh unitless	sum k	running sum	M_Seismic k-ft		
F_t								0.1	0.1	10.12		
k	120	150	0	0	0.000	0.0	0.000	0.0	0.1	0	0	0
j	100	120	0	0	0.000	0.0	0.000	0.0	0.1	0	0	0
i	80	100	0	0	0.000	0.0	0.000	0.0	0.1	0	0	0
h	60	80	0	0	0.000	0.0	0.000	0.0	0.1	0	0	0
g	40	62.5	3.5	0.25	2.500	128.1	0.529	1.3	1.4	66.94	22.5	78.75
f	30	40	3.5	0.25	1.111	38.9	0.161	0.4	1.8	13.9	10	35
e	25	30	3.5	0.375	0.833	22.9	0.095	0.2	2.0	6.4	5	17.5
d	20	25	3.5	0.375	0.833	18.7	0.077	0.2	2.2	4.3	5	17.5
c	15	20	3.5	0.375	0.833	14.6	0.060	0.1	2.3	2.6	5	17.5
b	1	15	3.5	0.375	2.333	18.7	0.077	0.2	2.5	1.5	14	49
a	0	1	3.5	0.375	0.167	0.1	0.000	0.0	2.5	0.0	1	3.5
					8.610	242.0	1.000	2.5		mean diameter		3.5

106 k-ft ult
76 k-ft wk'g

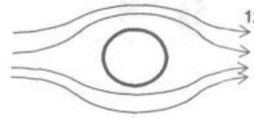
row 190

A	B	C	D	E	F	G	H	I	J	K	L	M	N
SEISMIC Incremental Moments													
	ft	k-ft	k-ft	k-ft	k-ft	k-ft	k-ft	k-ft	k-ft				k-ft
F_t		*0.0*											0.0
k	0	0.0	*0.0*										0.0
j	0	0.0	0.0	*0.0*									0.0
i	0	0.0	0.0	0.0	*0.0*								0.0
h	0	0.0	0.0	0.0	0.0	*0.0*							0.0
g	22.5	14.7	0.0	0.0	0.0	0.0	*1.5*						16.2
f	10	2.0	27.8	0.0	0.0	0.0	0.0	*2.2*					31.9
e	5	0.6	4.0	34.3	0.0	0.0	0.0	0.0	*2.5*				41.4
d	5	0.5	1.8	5.9	40.8	0.0	0.0	0.0	0.0	*2.87*			51.9
c	5	0.4	1.4	2.9	7.9	47.3	0.0	0.0	0.0	0	*3.21*		63.2
b	14	1.3	2.5	4.1	6.2	13.5	48.7	0.0	0.0	0	0	*4.15*	80.4
a	1	0.0	1.5	2.6	4.3	6.4	38.3	66.9	0.0	0	0	0	124.3
	62.5											*4.22*	

SEISMIC Lateral Deflections													row 210
			segment^2	*y_incr*			*delta*			*theta*	*theta*		
	Area	I corroded	EI	d_W	d_Q	d_M	sum		theta W	Q	M	sum	
	ft^2	ft^4	1/k	ft	ft	ft		1/k	ft	ft	ft		
Ft	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.00	0.00	0	
k	0.00	0.00	0	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.00	0.00	0	
j	0.00	0.00	0	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.00	0.00	0	
i	0.00	0.00	0	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.00	0.00	0	
h	0.00	0.00	0	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.00	0.00	0	
g	0.23	0.26	0.000453	0.0017	0.0044	0.0037	0.0098	0.000453	0.0022	0.00	0.01	0.014	
f	0.23	0.26	8.95E-05	0.0000	0.0001	0.0014	0.0016	0.000291	0.0002	0.00	0.01	0.01	row 220
e	0.34	0.44	1.34E-05	0.0000	0.0000	0.0003	0.0003	0.000101	0.0000	0.00	0.00	0.004	
d	0.34	0.44	1.34E-05	0.0000	0.0000	0.0003	0.0004	0.000114	0.0000	0.00	0.01	0.006	
c	0.34	0.44	1.34E-05	0.0000	0.0000	0.0004	0.0004	0.000128	0.0000	0.00	0.01	0.008	
b	0.34	0.44	0.000105	0.0000	0.0001	0.0042	0.0044	0.000462	0.0002	0.00	0.04	0.037	
a	0.34	0.44	5.37E-07	0.0000	0.0000	0.0000	0.0000	3.36E-05	0.0000	0.00	0.00	0.004	
						sum 1	0.0168 ft					0.085 ft	
												0.101 ft	
												1.218 in	
													row 230

row 240

row 250



ENGINEERING with the SPREADSHEET

23 Vortex Shedding.xls

A B C D E F G H I J K L M N

THE NATURAL FREQUENCY T_n OF A STRUCTURE .....

W_input **1** 0 = default, 1 = input

Conjugate Beam Method for calculating T_n
PVDH pg 123

	volume in^3	default	W input	weight	
k	0	0.0	**0.0**	0.000	
j	0	0.0	**0.0**	0.000	
i	0	0.0	**0.0**	0.000	
h	0	0.0	**0.0**	0.000	
g	8906	2.5	**1.8**	1.801	row 260
f	3958	1.1	**0.8**	0.789	
e	2969	0.8	**0.6**	0.645	
d	2969	0.8	**0.6**	0.645	
c	2969	0.8	**0.6**	0.645	
b	8313	2.4	**2.0**	1.965	
a	594	0.2	**0.2**	0.200	
base		8.7	6.7	6.690 k	

	dx ft	M k-ft											sum M's
k	0												
j	0	0											0
i	0	0	0										0
h	0	0	0	0									0
g	11.25	0	0	0	0								0
f	16.25	25	0	0	0	0							25
e	7.5	9	46	0	0	0	0						56
d	5	4	14	57	0	0	0	0					76
c	5	3	7	18	66	0	0	0	0				95
b	9.5	5	8	12	24	79	0	0	0	0			128
a	7.5	17	10	13	17	31	95	0	0	0	0		183
base	1.5	1	26	13	16	20	34	103	0	0	0	0	213

	I corroded plate from above ft^4	M/I k/ft^3	segment	dx	M dx/I k/ft^2	running sum	M dx^2 /I k/ft	running sum	y ft	Wy k-in 0	Wy^2 $k\text{-}in^2$
k	0.00	0	0					627509.7	0.000	0	0
j	0.00	0	0	0	0	13454	0	627509.7	0.000	0	0
i	0.00	0	0	0	0	13454	0	627510	0.000	0	0
h	0.00	0	0	0	0	13454	0	627510	0.000	1.399	0
g	0.26	94	22.5	11.25	530	13454	151360	627510	0.148	0.867	2.48034
f	0.26	211	10	16.25	2480	12925	214328	476150	0.112	0.477	1.16634
e	0.44	173	5	7.5	1439	10445	87636	261822	0.062	0.317	0.35265
d	0.44	217	5	5	974	9006	48627	174185	0.041	0.697	0.15609
c	0.44	292	5	5	1272	8031	42592	125559	0.030	0.047	0.24721
b	0.44	418	14	9.5	3370	6759	70255	82966	0.020	0.24	0.01099
a	0.44	486	1	7.5	3390	3390	12711	12711	0.003		0.00862
base									sum Wy	4.044	

T_n	**0.334**	sec/cycle	2 * pi * (sumWy^2 /(g * sumWy))^0.5
f_n	**2.991**	Hz	

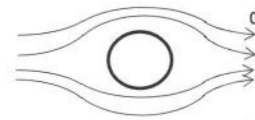
sum Wy^2 4.42224

Check T_n Against Simple Formula ....

t_	0.1875	in	plate thickness from row 156 above
w_	0.111	k/ft	
T_n	**0.380**	sec/cycle	0.0000027 * (Height /d)^2 * (wd /t)^0.5
f_n	**2.629**	Hz	to compare with 2.991 above

simplified calculation for uniform shell
PVDH pg 121

row 310



ENGINEERING with the SPREADSHEET

23 Vortex Shedding.xls

A B C D E F G H I J K L M N

VORTEX SHEDDING and FORCES on the CYLINDER PVDH

Note: the drag coefficient varies from 0.9 to 1.1 at low R_e values.

At R_e values greater than 5 E+5 the drag coefficient drops to 0.3 to 0.5.

R_e = Reynolds number

first critical velocity -- consider winds below 60 mph only

0.20 is the dimensionless Strouhal number for R_e between 10^3 to 10^5

PVDH pg 112 & DPE pg 246

First Check

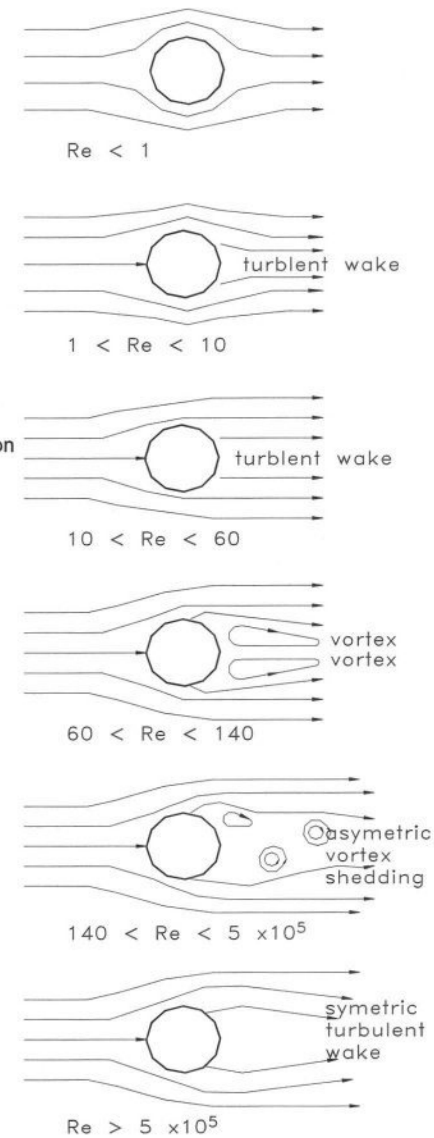
V_wind	**15.0**	mph	velocity of air
V_wind	22	ft/sec	
ρ_air	2.40E-03	lb-sec^2 /ft^4	air mass density
d_mean	3.5	ft	diameter of cylinder
m_air	3.80E-07	lb-sec/ft^2	viscosity of air
R_e	4.86E+05	unitless	r_air * V_wind * d_mean / m_air
			where R_e < 5 E+05 is critical in vortex shedding

!!! vortex shedding at 15.0 mph per Re

Second Check

V_wind	**30.0**	mph	
V_wind	44	ft/sec	
R_e	9.73E+05	unitless	not critical at 30.0 mph per Re

V applied	15.0	mph	velocity of air
q_{wind}	0.58	lb/ft^2	0.00257 * (V mph)^2 generic wind pressure calculation
q	0.58	lb/ft^2	ρ_air * V^2 /2 acting on the front of the stack
C_D	**1.0**		coefficient of drag drops to about 0.5 at $R_e > 10^5$
D	**0.58**	lb/ft^2	C_D * ρ_air * V^2 /2 parallel to air flow
C_L	**0.6**		coefficient of lift
L_	**0.35**	lb/ft^2	C_L * ρ_air * V^2 /2 force on stack at critical wind velocity



row 320

row 330

row 340

row 350

row 360

Figure 23-4 Vortex shedding and Reynolds numbers; vortex periodicity vanishes at $R_e > 5 \times 10^5$

PVDH page 117 and DPE page 246

M.F. Table 4.3 PVDH

row 370

VORTEX SHEDDING IN TALL STACKS AND VESSELS
EXHAUST STACK

A B C D E F G H I J K L M

CRITICAL WIND VELOCITIES PVDH

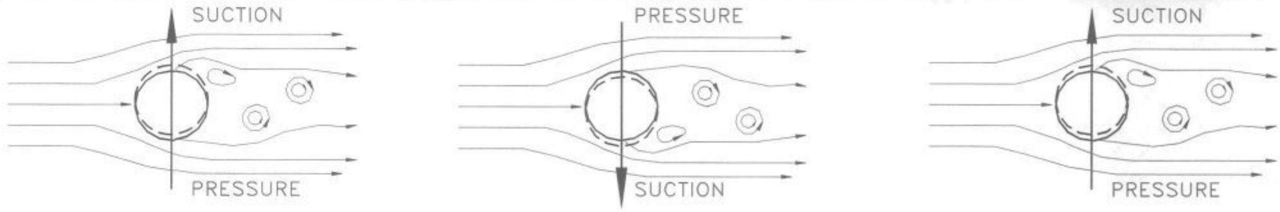


Figure 23-5 VORTEX SHEDDING -- TRANSVERSE VIBRATION

$S = f_v\, d / V$ Strouhal number

substitute f = 1/Tn for fv

$S = f\, T_n\, d / V$

$V = d / T_n / S$

For values of R_e of 140 to 50000 and S = 0.18 to 0.21, the first critical velocity is:

$V = d / T_n / 0.2 = 5\, d / T_n$ fps

$V = 3600$ sec/hour / 5280 ft/mile * $5\, d / T_n = 3.41\, d / T_n$ miles/hour

d	logarithmic decrement for damping
M.F.	magnification factor, conservatively p /d
S	dimensionless parameter, Strouhal number
f_v	shedding frequency of vortices, Hz
d	diameter of cylinder perpindicular to wind flow, ft
V	wind velocity, ft/sec
V_1	first critical velocity at which vortex shedding frequency equals the natural frequency of the structure

d_mean	3.50	ft	mean stack diameter from row 187 above
V_1	**35.6**	mph	3.4 * d_mean /T_n
			3.4 * 3.50 / 0.334
	52.2	ft/sec	

35.6<60 mph by -69 %
35.6<150 mph by -322 %

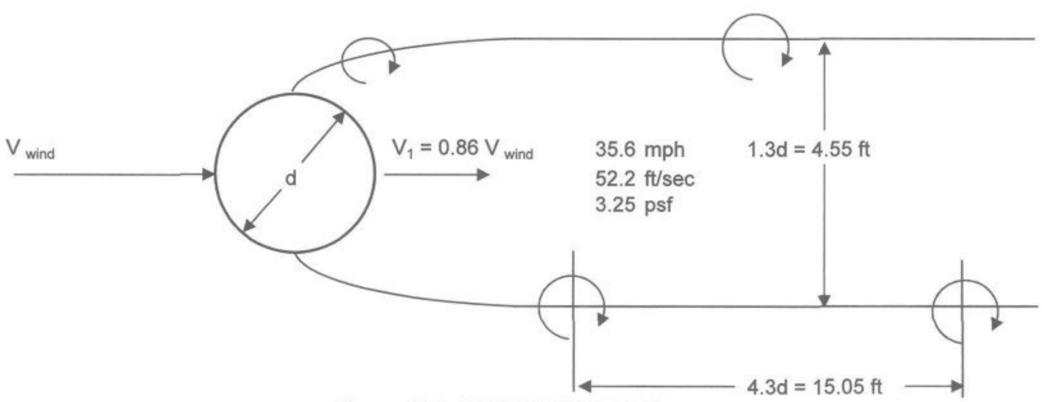


Figure 23-6 VORTEX SHEDDING

V_2	**222.4**	mph	6.25 * V_1 second critical velocity

222.4>60 mph by 73 %
222.4>150 mph by 33 %

23 Vortex Shedding.xls

A B C D E F G H I J K L M N

OVERTURNING MOMENT with FOUNDATION MAGNIFICATION FACTOR

Table 23 - 1 -- DAMPING AND MAGNIFICATION FACTORS

Footing Average Values	Soft Soils		Stiff Soils		PVDH Rock, Very Stiff Soils	
	d	M.F. max	d	M.F. max	d	M.F. max
Tall Process Columns	0.126	25	0.080	39	0.052	60
Unlined Stacks	0.105	30	0.052	60	0.035	90
Lined Stacks	0.314	10	0.105	30	0.070	45

row 440

Height	**62.5**	ft	from row 72 above
M.F.	**60**		foundation magnification factor
C_L	**0.6**		coefficient of lift
L	117.63	lb/ft^2	C_L * M.F. * ρ_air * (V_1 * 5280/3600)^2 / 2 for V_1 in mph
F_1	**8.58**	k	L * d * Height /3 /1000 lb/k *force acting at top of stack*
M_res1	**536.1**	k-ft	Height * F_1 at 35.6 mph M_wind 345 < M_Resonance 536 k-ft **GOVERNS**
h	**2.00**	**ft**	**depth of footing from input above**
M res1 ftg	**553**	**k-ft**	
F_2	335	k	
M_res2	20940	k-ft	Height * F_2 at 222.4 mph This is not of interest when V_2 is above 60 mph

C_L coefficient of lift generally 0.4 to 0.6 where 0.6 is conservative

L pressure transverse to the wind direction at resonance on the projected cylinder area, psf

row 450

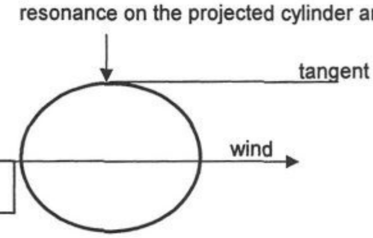
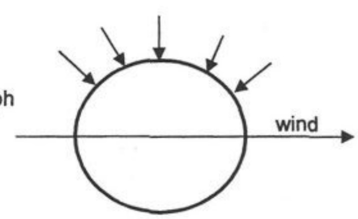


Figure 23-7 TRANSVERSE FORCE

row 460



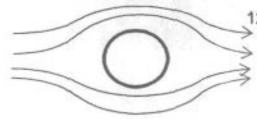
A substantial amount of force is generated perpendicular to the direction of the wind. You can observe this in your car's solid radio antenna. At various speeds the antenna will wave side to side and sometimes the motion will be circular which is a combination of back and forth whipping and side to side whipping.

Figure 23-8 NORMAL FORCE

row 470

row 480

row 490



CANTILEVER VIBRATION DPE

Ovaling calculations and vortex shedding are based upon the plate thickness at the top of the stack.
Shell thickness is determined at locations where plate thickness changes with the appropriate moments and loads at those levels.

f	2.991	Hertz	natural frequency from calculations above	
V_c	**35.59**	mph	$3.41 * f * D_r$	DPE page 246
			3.41 * 2.991 Hz * 3.490 ft	

V_{30}	**150**	mph	from above
$L_{effective}$	**62.5**	ft	from above
V_w	167	mph	$V_{30} *(L/30)^{0.143}$
V_w max	195	mph	$1.3 * V_{30}$
V_w	167	mph	minimum (V_w, V_w max)

For values of R_e of 140 to 50000 and S = 0.18 to 0.21, the first critical velocity is: row 500

$V = d / T_n / 0.2 = 5\ d / T_n$ fps

$V = 3600$ sec/hour / 5280 ft/mile $* 5\ d / T_n = 3.41\ d / T_n$, miles/hour

The weight of the stack should be equal to or greater than the corroded weight of the stack pluss refractory lining (which reduces vibration frequency) DPE 247.

V_c	critical wind velocity, mph
V_w	maximum wind velocity, mph
V_{30}	wind velocity at 30 ft above grade, mph

D_r	**3.49**	ft	average diameter at the top of the stack
W_s	**5.208**	k	weight of corroded stack including attachments **say 3/4 * 6.944 k**

K_1 ratio of critical wind velocity to weight of stack, unitless. Use refractory lining as part of weight to help reduce vibration. row 510

$q_{critical}$	3.3	lb/ft^2	$0.00257 * V_c^2$
			0.029884

L_e	effective length of stack
E	Youngs modulus of elasticity, ksi
$q_{critical}$	$P_{critical}$ in DPE, pressure at critical wind velocity, psf

K_1'	0.136	unitless	$q_{critical} * D_r * L_e / W_s$ / 1000 lb/k
			3.3 * 3.49 * 62.5 /5.208 /1000
E	**29500**	ksi	from above
K_1''	13.320	unitless	$0.0077 * D_r^{5} * E /(L_e^3 * W_s) * 144\ in^2 / ft^2$
			0.0077 * 3.49^5 * 29,500 /(62.5^3 * 5.208) * 144
K_1	13.320	unitless	
limit	0.067		1 /15 ratio

unit analysis

$\frac{lb}{ft^2}\ \ ft\ \ \frac{ft}{k}\ \ \frac{1000\ k}{lb}$

$\frac{ft^5\ \ k}{in^2}\ \ \frac{1}{ft^3}\ \ \frac{1}{k}\ \ 144\ \frac{in^2}{ft^2}$

13.320 > 1/15 CHECK CANTILEVER VIBRATION

row 530

NOTE: This flag operates using IF statements.

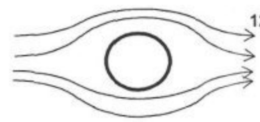
row 540

row 550

CONSULTING COMPANY

VORTEX SHEDDING IN TALL STACKS AND VESSELS

EXHAUST STACK



ENGINEERING with the SPREADSHEET

23 Vortex Shedding.xls

A B C D E F G H I J K L M N

DEFLECTION CALCULATED AS STATIC DEFLECTION DPE

I_s	**0.260** ft^4	see calculations at row 135 above moment at top half of stack
D_s	0.034 in	$q_{critical} * D_r * L_e^4 / (8 * E * 1000\ lb/k * I_{top}) * 12 / 1000$ static deflection 3.26 * 3.49 * 62.5^4 / (8 * 29,500 * 1000 * 0.260) * 12 /1000

unit analysis

$$\frac{lb/ft^2 \quad ft \quad ft^4}{k/in^2 \qquad\quad ft^4} = \frac{lb \quad in^2 \quad ft \quad ft^4}{ft^2 \quad k \qquad\quad ft^4}$$

row 560

$$= \frac{lb}{k}\ \frac{in^2}{ft}\ \frac{k}{1000\ lb}\ \frac{ft}{12\ in} = \frac{in \qquad 12}{1000} = in$$

M.F.	**60** unitless	magnification factor from Table 23-1 above.
$D_{cantilever}$	**2.03** inch	amplitude of vibration ← $D_{cantilever}$ $w L^4 / (8 E I)$

Ratio PDVH wind incremental deflection to DPE resonant deflection
and multiply PDVH incremental wind moment. row 570

M vortex	**165.0** k-ft	2.03" /4.27" * 346.4 k-ft

Damping Stability

Table 23 - 2 -- LOGARITHMIC DECREMENTS FOR DIFFERENT TYPES OF STRUCTURES row 580

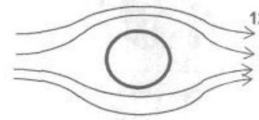
Type of Construction	Lining	Decrement d
Welded	None	0.03
Welded	Gunite	0.05
Welded	Tower Full of Water	0.07
Riveted	Brick	0.05

$\varepsilon_{damping}$	**0.03** unitless	damping factor for type of structure	DPE page 264
D_r	**3.490** ft	average internal diameter of top half of stack	
W	**6.9** k	from above	row 590
L	**62.5** ft	over all height	
D_F	**0.27 !!!**	$We / (LD_r^2)$ 6.9 k * 1000 * 0.03 /(62.5 ft * 3.490^2)	$D_F < 0.75$ unstable $0.75 < D_F < 0.95$ $D_F > 0.95$

$$k \quad \frac{1000\ lb}{k} \quad unitless \quad \frac{1}{ft} \quad \frac{1}{ft^2}$$

row 600

row 610



A B C D E F G H I J K L M N

ALLOWABLE SHELL BUCKLING STRESS Bottom Shell

E_heat	**26099**	ksi	E approximated for heat		
Fy_heat	**36**	ksi	F_y approximated for heat		
Sc_1	18.00	ksi	F_y /2	DPE page 242	
D_Mean	3.500	ft	mean stack diameter from row 187 above		
t_shell	**0.3125**	in	t shell for corroded plate		
ratio_c	0.00446		t_shell /D_Mean		
	0	logic	t_shell /D_Mean < 0.00425		row 620
ratio_c	0.00425				
Sc_2	15.93	ksi	0.56 * ratio_c * E' /(1+ 0.004 * E' /Fy')	where ratio_c = min(t_shell /D_Mean, 0.00425)	

limit compression stress to (0.85 weld efficiency) * (Fy at temperature) / (FS = 2)

Sc_3	15.30	ksi	0.85 * Fy' /2
S_c	**15.30**	ksi	allowable shell stress

Required Shell Thickness row 630

W_t	**6.690**	k		DPE page 242
M	**536.1**	k-ft	vortex shedding	
t_r	**0.3068**	in	$(W_t * D\_mean + 48 * M) /(p * D\_mean^2 * S_c)$	

Required plate thickness to resist
DL + LL + M wind or seismic

Check Against P/A + Mc/I .....

W_sum	6.690	k	P	
M_wind	**346.4**	k-ft	wind calculated per traditional method above	row 640
M_vortex	536.1	k-ft		
M_gov	536.1	k-ft	M_wind 345 < M_Resonance 536 k-ft	
D_sect	**41.625**	in	diameter at centerline of shell plate	
t_shell	**0.3125**	in	**PL 3/8 corroded plate at base**	
A_sect	40.87	in^2		
I_sect	0.43	ft^4		

q	P/A	Mc/I	**15.290**	ksi	
	0.164	15.127	**-14.963**	ksi	
	1	logic			row 650

Sc > q OK

Sc 15.30 > q 15.290 ksi required OK...

Vibration Analysis for the Life of the Structure

F_u	60	ksi		PVDH page 118
n	5			
K	780000			
S_R	36	ksi	$S_R = 2\ S$	

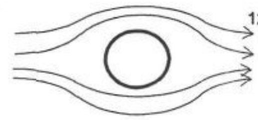
row 660

Table 23 - 3 -- TYPE of CONSTRUCTION b FACTOR

β	1.20	shell with a smooth finish
β	1.80	butt-weld joints
β	3.00	fillet weld or incompete penetration groove weld with root unsealed

N	9.24E+35	cycles	$(K /b\ S_R)^n$
T_n	0.380	sec/cycle	
L_e	**9.76E+31**	hours	$N * T_n$ /3600 seconds /hour
	1.11E+28	years	

row 670



A	B	C	D	E	F	G	H	I	J	K	L	M	N

ALLOWABLE SHELL BUCKLING STRESS Top Shell

E_heat	**26099**	ksi	E approximated for heat		
Fy_heat	**36**	ksi	F_y approximated for heat		
Sc_1	18.00	ksi	F_y /2	DPE page 242	
D_Mean	3.500	ft	mean stack diameter from row 247 above		
t_shell	**0.1875**	in	t shell for corroded plate		
ratio_c	0.05357		t_shell /D_Mean		
	0	logic	t_shell /D_Mean < 0.00425		row 680
ratio_c	0.00425				
Sc_2	15.93	ksi	0.56 * ratio_c * E' /(1+ 0.004 * E' /Fy')	where ratio_c = min(t_shell /D_Mean, 0.00425)	

limit compression stress to (0.85 weld efficiency) * (Fy at temperature) / (FS = 2)

Sc_3	15.30	ksi	0.85 * Fy' /2
S_c	**15.30**	ksi	allowable shell stress

Check Against P/A + Mc/I ..... row 690

W_sum	**6.690**	k	P
M_wind	132	k-ft	wind calculated per traditional method above
M_vortex	205.0	k-ft	M_wind 0 < M_Resonance 536 k-ft
M_gov	205.0	k-ft	
D_sect	**41.75**	in	diameter at centerline of shell plate
t_shell	**0.3125**	in	**PL 3/8 corroded plate at base**
A_sect	40.99	in^2	
I_sect	0.43	ft^4	

row 700

q	P/A	Mc/I	**5.913**	ksi
	0.163	5.750	**-5.587**	ksi

1 logic
Sc > q OK
Sc 15.30 > q 5.913 ksi required OK...

row 710

row 720

row 730

23 Vortex Shedding.xls

A B C D E F G H I J K L M N

OVALING SMACNA

The SMACNA calculation is a fundamental calculation demonstrating the roots of the ovaling calculations. Other calculations do not include the units or background for some of the numbers used. This may be because some of these calculations are empirical or the factors are a series of calculations that have been boiled down for ease of use.

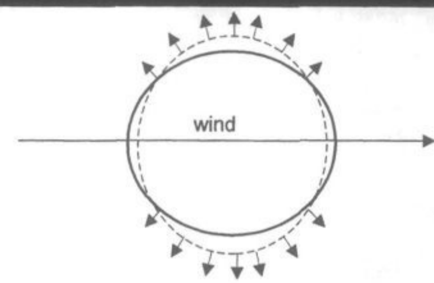


Figure 23-9 OVALING

The entire SMACNA calculation is: row 740

$$f_n = \frac{2n\,(n^2 - 1)}{p\,D^2\sqrt{r\,(n^2 + 1)}}\sqrt{\frac{E\,I}{A}}$$

This calculation is broken up for construction and trouble shooting purposes.

$f = 1/2p\,(k * g/W)^{0.5}$ for a mass on the free end of a spring, other end fixed

Unit analysis is used here to document the results.

T = 1/f

n	**2**	unitless	mode of vibration
t_x	**0.1875**	in	corroded plate thickness (row 750)
b	10	in	arbitrary starting point for the estimation of a built-up member compression flange
A PL	1.875	in^2	
I PL	0.001030	in^4	10 * 0.1875 * 0.1875^3 /12
E heat	26099	k/in^2	
num_2	119.74	$lb^{0.5}$	(E_heat_ *1000 * I_Plate /A_PL)^0.5
r	15.06	$lb\text{-}sec^2/ft^4$	(row 760)
$r^{0.5}$	3.88	$lb^{0.5}\text{-}sec/ft^2$	
d_mean	3.490	ft	diameter of section under consideration from above
d_mean^2	12.180	ft^2	
num_1	1.708	unitless	2 * n * (n^2 - 1) /(PI() * (n^2 + 1)^0.5)
			2 * 2 * (2^2 - 1) /(PI() * (2^2 + 1)^0.5) (row 770)
f_n	**4.33**	cycle/sec	

$$num_2 = \left[\frac{26099\ k}{in^2}\ \frac{1000\ lb}{k}\ 0.00103\ in^4\ \frac{1}{1.875\ in^2}\right]^{0.5}$$

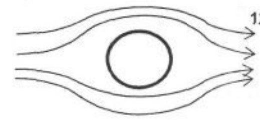
$$r = \frac{485\ lb}{ft^3}\ \frac{sec^2}{32.2\ ft}\ \text{mass}$$

$$f_n = 1.708\ num_1\ \text{unit}\ \frac{1}{12.180\ ft^2}\ \frac{ft^2}{3.88\ lb^{0.5}\text{-}sec}\ 119.74\ num_2\ lb^{0.5}$$

k	spring constant, lb/in
g	gravity, 386 in/sec^2, 32.2 ft/sec^2
W	weight, lbs
mass	W /g, lb-sec^2 /in
f	frequency, cycle/sec, Hertz
T	period, seconds/cycle
p	pi, pi(), 3.14 unitless
num	numerator
den	denominator

row 780

row 790



A	B	C	D	E	F	G	H	I	J	K	L	M	N

OVALING PVDH

t PL	**0.1875**	in	corroded shell thickness	PVDH page 119
m	0.000136	lb-sec^2/in	/in = lb-sec^2/in^2	mass lb-sec^2/in
			mass per unit length of ring	
			485 lb/in^3 /1728 in^3/ft^3 * 0.1875 /386 in/sec^2	
R	20.94	in	radius to centerline of shell	
T_oval	0.073	sec/cycle	2 * p /2.68 * (m * R^4 /(E_heat * 1000 * I_Plate))$^{0.5}$	row 800
			2 * pi() /2.68 * (0.000136 * 20.94^4 /(26,099 * 1000 * 0.001030))^0.5	
f oval	13.66	Hz	1 / T_oval	
V_1oval	**81.0**	mph	3.4 * d_mean /(2 * T_oval)	
V_1oval'	**60.2**	mph	1120 * t_x /d_mean	row 810

$$\left(\frac{lb\text{-}sec^2}{in^2}\ \ in^4\ \ \frac{in^2}{k}\ \ \frac{k}{1000\ lb}\ \ \frac{1}{in^4}\right)^{1/2}$$

OVALING DPE

fr_oval	**10.29**	Hz	7.85 * t_x * E heat^0.5 /(60 * D_mean^2)	DPE page 249
			7.85 * 0.1875 * 26,099^0.5 /(60 * 3.50^2)	
T	0.097	sec/cycle		Design to 66 fps = 45 mph
fv	**3.782**	Hz	0.2 * (V = 66 fps) /D_mean	
T	0.264	sec/cycle		row 820
critical	1	logic	fv < 2 * fr_oval	
		!!! Stiffening rings required		S — dimensionless parameter, Strouhal number usually 0.18 to 0.22 in this range of Reynolds (R_e) numbers
V_0	5386.4	fpm	60 * f_r * D /(2 * S)	
	89.8	fps		
	61.2	mph		H_r — spacing between rings, ft
				V_0 — critical ovaling velocity, fpm, feet/minute
H_r	**16.00**	ft	spacing between rings	
S_t	15.30	ksi	from above	
S_m	**0.259**	in^3	required section modulus at ring	row 830
b	11.25	in	60 * t_x rule of thumb for plate deck	
S plate	**0.066**	in^3		
critical	1	logic	S plate < S_m	
		!!! Stiffening rings required		

OVALING

V design	**45**	mph		
q	5.20	lb/ft^2	0.00257 * V^2 /2	row 840
Radius	1.745	ft		
M max	4.98	lb-ft/ft	0.314 * q * Radius^2	
S req'd	**0.062**	in^3	for stiffener spacing = 16.0 ft	

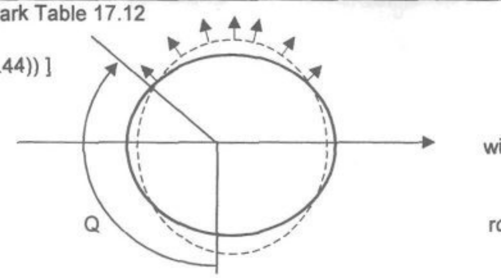
ROARK -- APPROXIMATE A PARTIALLY LOADED RING — row 850

A B C D E F G H I J K L M N

ROARK -- APPROXIMATE A PARTIALLY LOADED RING

Θ	2.44	radians	
	140	degrees	Q /p 180
M	7.21	lb-ft/ft	2.5 * 5.20 * 1.745^2 * [2.44 /PI() * (1 + COS(2.44))]
S req'd	**0.090**	in^3	7.21 * 12 /15.30 /1000 * 16.00
			for stiffener spacing = 16.0 ft

Roark Table 17.12



row 860

Figure 23-10 OVALING ESTIMATE

STIFFENER DESIGN

t'	0.1875	in	corroded thickness
f'	15.3	ksi	

shooting method to achieve convergence for b row 870

where b = 253 *t / f $^{0.5}$ * (1 - 50.3 /((be /t) * f $^{0.5}$)) as in the flange of a rectangular section

be	1.875	2.765	2.967	3.083	3.156	3.205	3.239	3.262	3.278
b	-3.468	1.554	2.273	2.643	2.863	3.005	3.099	3.163	3.208

Calculate L without accounting for fillet and rounded toes -- values will be the same as AISC

L t	**0.125**	
L Length	**2**	in
L Flange	**2**	in
L A	**0.484375**	in^2

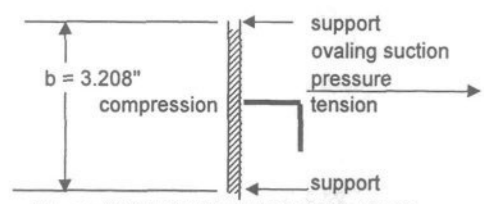


Figure 23-11 COMPRESSION FLANGE

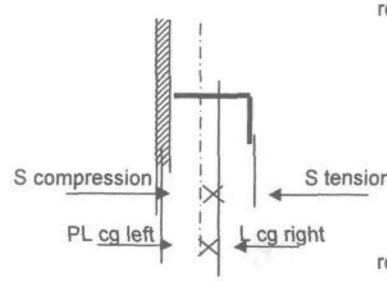
	arm	area	q
Length	1.0000	0.250	0.250
Flange	1.9375	0.234	0.454
		q sum	0.704

CG x **1.454** in from left fiber of L vertical leg

	A	d	d^2	Ad^2	I
Length	0.250	0.454	0.206	0.051	0.083
Flange	0.234	0.484	0.234	0.055	0.000
			sum I	**0.190** in^4	

row 890

	A	cg x	I	A cg	d	A d^2
L	0.484	1.454	0.190	0.795	0.857	0.584
PL	0.602	0.09375	0.001762	0.056	0.690	0.027
Area	**1.086** in^2		cg	**0.784** in		
					I sum	**0.803** in^4



S tension	**0.936**	in^3	I /d right
S_compr	**-1.163**	in^3	I /d left

row 900

Figure 23-12 STIFFENER RING

T_oval	**0.003**	sec/cycle	2 * p /2.68 * (m * R^4 /(E_heat * 1000 * I_Plate))$^{0.5}$
			2 * pi() /2.68 * (0.000136 * 20.94^4 /(26,099 * 1000 * 0.803))^0.5
f oval	**381.304**	Hz	1 / T_oval
V_1oval	**2262**	mph	3.4 * d_mean /(2 * T_oval)

row 910

23 Vortex Shedding.xls

A B C D E F G H I J K L M N

BREECHING

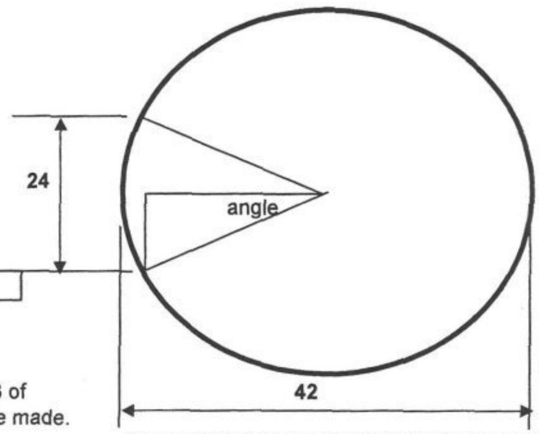
Manhole Access

General rules for openings per SMACNA.

For arc of shell removed

diameter	**42**	in
chord	**24**	in
angle	0.6082	radians
chord	1.2165	radians
arc	25.5463	in
PL t	**0.375**	
PL area	**9.58**	in^2 in cross-section

row 920



Replace this area with vertical stiffeners to assure a shell structure with as much or a greater Ixx. This applies until the opening width is greater than 2/3 of the stack diameter. Then, a detailed analysis must be made.

Figure 23-13 PLAN VIEW AT MANHOLE IN SHELL

row 930

Use L 4 x 4 x 3/4 on each side of opening. A = 10.88 in^2.

Stiffeners to extend a minimum of 3/4 the width of the opening above and below the opening.

Intake Breeching

For shell minus arc

dia breech	**42**	in
chord	**36**	in
angle	1.0297	radians
	58.9973	degrees
chord	2.0594	radians
arc	43.0542	in
PL t	**0.375**	in
PL area	16.08	in^2 arc in cross-section

row 940

yc	0	zc	17.3248	in
I_{xx} arc	1989	I_{yy} arc	4974	in^4
area	49.04	area	49.04	in^2
I_{xx} circle	10622	I_{yy} circle	10622	in^4
cg_y	0.0000	cg_x	-8.4487	
I_{xx} shell	**8633**			

row 950

arc	16.08	17.3248	278.50
circle	49.04	0	0
			-278.50
a shell	32.9633		
cg x	-8.4487		

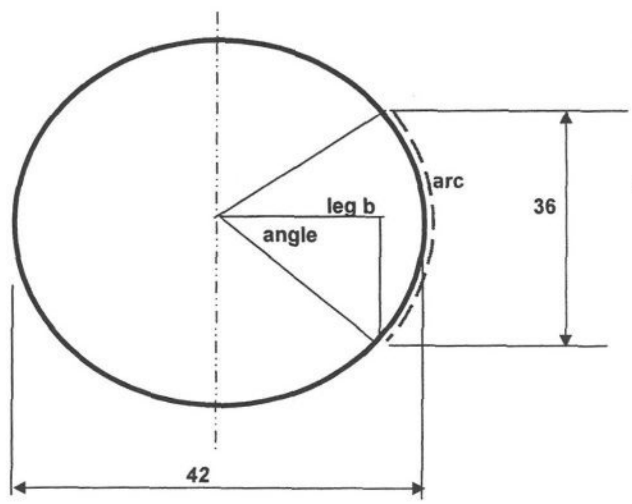


Figure 23-14 PLAN VIEW AT BREECHING IN SHELL

	I_{yy}	a	d_x		ad_x^2
arc	4974	16.08	17.1373	275.482	4721
circle	10622	32.96	-8.4487	-278.496	2353
				sum I_{yy}	**3279** in^4

row 970

BREECHING -- Continued

AutoCAD Mass Properties of Shell Minus Arc
Area: 32.9654
Perimeter: 176.5653
Bounding box: X: -21.0000 -- 10.8166
Y: -21.0000 -- 21.0000
Centroid: X: -8.4473
Y: 0.0000
Moments of inertia: X: 8632.8991
Y: 5647.5443
Product of inertia: XY: 0.0000
Radii of gyration: X: 16.1826
Y: 13.0888
Principal moments and X-Y directions about centroid:
I: 3295.2498 along [0.0000 -1.0000]
J: 8632.8991 along [1.0000 0.0000]

AutoCAD Mass Properties of Arc
Area: 16.0729
Perimeter: 86.4723
Bounding box: X: 10.6235 -- 21.0000
Y: -18.0000 -- 18.0000
Centroid: X: 17.3253
Y: 0.0000
Moments of inertia: X: 1988.6813
Y: 4974.0361 row 980
Product of inertia: XY: 0.0000
Radii of gyration: X: 11.1233
Y: 17.5917
Principal moments and X-Y directions about centroid:
I: 149.5106 along [0.0000 -1.0000]
J: 1988.6813 along [1.0000 0.0000]

row 990

L Reinforcing
leg b **10.6235** in

Calculate L without accounting for fillet and rounded toes -- values will be the same as AISC

L t	**0.625**	
L Length	**11**	in
L Flange	**4**	in
L Area	**8.984**	in^2

row 1000

L cg calculations

	arm_x	area	$q = arm_x\ a$	arm_y	$q = arm_y\ a$
Length	5.5000	6.875	37.813	0.3125	2.148438
Flange	10.6875	2.109	22.544	2.3125	4.87793
		q sum	60.356		7.026

$L\ cg_x$ **6.718** in from left fiber of L horizontal leg
$L\ cg_y$ **0.782** in from the bottom fiber of L horiz leg

$L\ I_{yy}$	A	d	d^2	Ad^2	I
Length	6.875	1.218	1.483	10.198	69.323
Flange	2.109	3.970	15.757	33.238	0.069
sum A	**8.984** in^2			sum I_{yy}	**112.828** in^4

row 1010

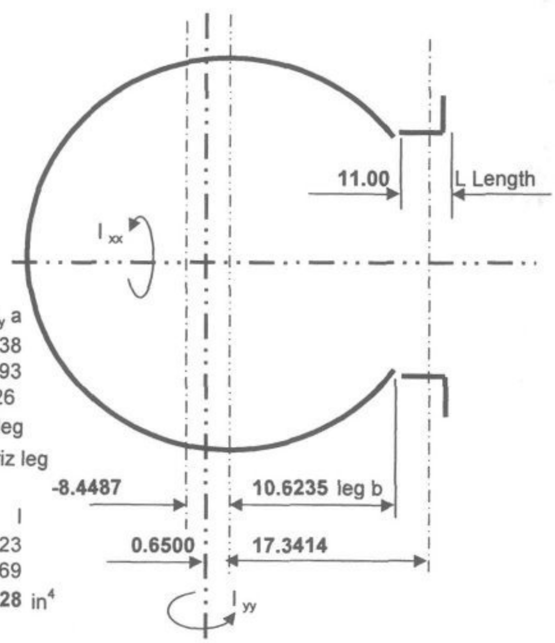
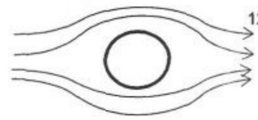


Figure 23-15 PLAN VIEW REINFORCING AT BREECHING

row 1020

row 1030



BREECHING -- Continued

	arm_x	area		
L's cg x	17.3414	17.97		311.6
Shell cg x	-8.4487	32.96		-278.5
	sum A	50.93	q sum	33.108
comp x	**0.6500** in			

row 1040

	I_{yy}	A	d		Ad^2
2 - L's	226	17.97	16.8846	303.39	5123
Shell	3279	32.96	-9.0987	-299.92	2729
		50.93		sum I_{yy}	11356 in^4
		-5.8887			

AutoCAD Mass Properties of Shell Composite Profile
Area: 40.4654
Perimeter: 208.5653
Bounding box: X: -16.7363 -- 20.1387
Y: -21.0000 -- 21.0000
Centroid: X: 0.0000
Y: 0.0000
Moments of inertia: X: 11274.7741
Y: 6427.2093
Product of inertia: XY: 0.0000 row 1050
Radii of gyration: X: 16.6921
Y: 12.6029
Principal moments and X-Y directions about centroid:
I: 11274.7741 along [1.0000 0.0000]
J: 6427.2093 along [0.0000 1.0000]

L I_{xx}	A	d	d^2	Ad^2	I
Length	6.875	0.470	0.220	1.516	0.224
Flange	2.109	-1.530	2.342	4.941	2.002
sum A	**8.984** in^2			sum I_{xx}	**8.683** in^4

	I_{xx}	A	d		Ad^2
2 - L's	17.365	17.969	18.78207		6339
Shell	8633				
				sum I_{yy}	**14989** in^4

For Comparison

Circle	10622 in^4
Shell $_{xx}$ ↑	11356 in^4
Shell $_{yy}$ →	14989 in^4

row 1060

row 1070

row 1080

row 1090

BOLT CIRCLE

Bolts	**12**	unit	number of bolts
d_bolt	**1.75**	inch	gross diameter of bolt
n bolt	**5**	unit	threads per inch
$A_{threaded}$	1.8995	in^2	threaded portion of bolt in tension and shear
			0.7854 * (1.75 - 0.9743 /5)^2
BC	**54.00**	inch	diameter of bolt circle through bolt CL's
Base PL	**66.00**	inch	diameter of base plate / bolt ring
F bearing	**0.750**	ksi	bearing working stress max
d bearing	**7.500**	in	estimated depth in the direction of the FORCE
			iterate manually
leg a	20.95	in	((66.000/2)^2-(66.000/2-7.500)^2)^0.5
angle	0.8214	radians	20.95/(66.000/2-7.50)
A bearing	351.4	in^2	(66.000/2)^2*(0.8214-sin(0.8214)*cos(0.8214))
xc	**26.75**	**in**	**cg of bearing area**
F_u bolt	**105**	ksi	ultimate tension value of bolt material
E bolt	**29000**	ksi	young's modulus of elasticity
F_t	34.65	ksi	allowable tension on bolt
T bolt	65.82	k	

d inches	# bolts	ratio	T kips	M k-in
53.75	1	1.000	65.82	3538
45.84	2	0.853	112.27	5147
26.75	2	0.498	65.51	1752
7.66	2	0.142	18.76	144
			sum M	10580
		sum T	**262.35**	

C **263.6** k compression/bearing block
100.5% convergence

M_{ot}	**488.0**	k-ft	overturning moment
W	**6.944**	k	weight to resist overturning
M_{rt}	15.5	k-ft	righting moment
M bolts	881.7	k-ft	provided
M_net	472.5	k-ft	488.0 k-ft - 15.5 k-ft
$T_{bolt\ req'd}$	**35.3**	**K**	**472.5 /881.7 * 65.82 k bolt tension**

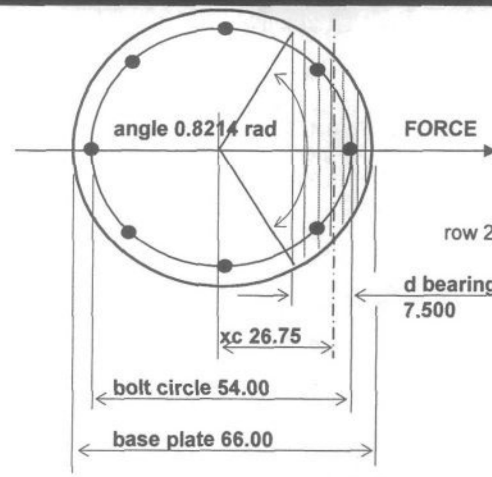


Figure 24-1 PLAN VIEW OF BOLT CIRCLE

row 20

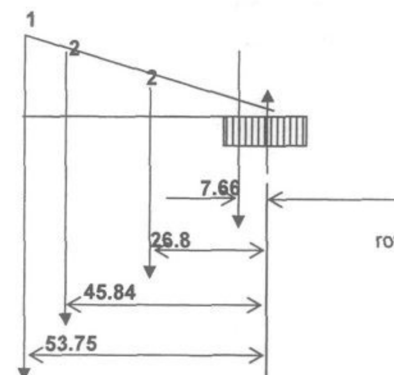


Figure 24-2 View of bolt strain diagram.

row 40

row 50

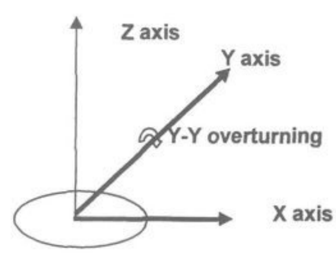


Figure 24-3 AXIS DIAGRAM

row 60

row 70

BOLT PATTERNS
EXHAUST STACK

A B C D E F G H I J K L M N

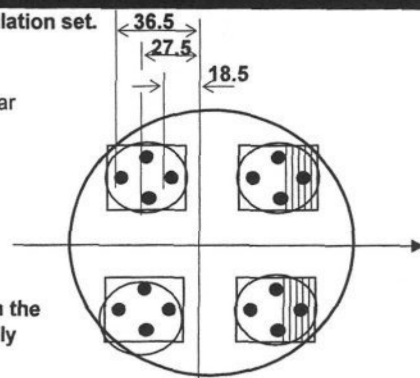
FOUR LEGS -- CIRCULAR BASE PLATES w/ FOUR BOLTS

This calculation is for a 4-legged tank and is not a part of the stack calculation set.

d_bolt	1.50	inch	gross diameter of bolt
n bolt	5	unit	threads per inch
$A_{threaded}$	1.3378	in^2	threaded portion of bolt in tension and shear
			0.7854 * (1.50 - 0.9743 /5)^2

Bolt Locations

A	36.5	in	far bolt(s)
B	27.5	in	CL of circular base plate
C	18.5	in	
Base PL	24.00	inch	diameter of base plate
F bearing	0.750	ksi	bearing working stress max
d bearing	7.500	in	**estimated depth of compression area in the**
	101.2%	convergence	**direction of the FORCE -- iterate manually**



row 80

Figure 24-4 PLAN VIEW OF BASPLATES

Circular Base Plates

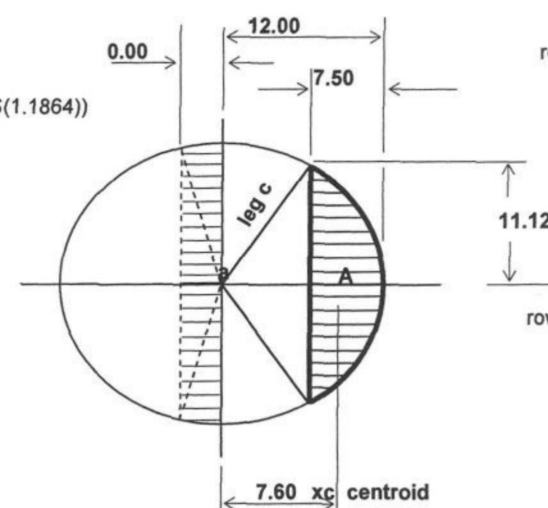
For a bearing area as a partially loaded semicircle to full semicircle

leg b	11.12	in	((24.00 /2)^2 - (24.00 /2 - 7.500)^2)^0.5
chord	22.25	in	
leg c	12.00	in	radius
angle a	1.1864	radians	atan(11.12 /(24.00 /2 - 7.50))
A segment	120.8	in^2	(24.00 /2)^2 * (1.1864 - SIN(1.1864) * COS(1.1864))
A semi c	226.2	in^2	area of semicircle
$A_{bearing\ 1}$	120.8	in^2	
xc	7.60	in	cg of bearing area 1
xc semi c	5.09	in	
$xc_{bearing\ 1}$	7.60		

row 90

For a bearing area as a loaded semicircle to fully loaded circle

angle a	4.3280	radians	
A segment	120.8	in^2	
$A_{bearing\ 2}$	347.0	in^2	A semi c - A segment
xc seg	-7.60	in	
$xc_{bearing\ 2}$	5.97	in	
A sum	120.8	in^2	
xc sum	-9.54	in	
xc sum	**7.60**	**in**	**for base plate bearing area**



row 100

Figure 24-5 Circular segment calculation.

row 110

F_u bolt	58	ksi	ultimate tension value of bolt material				
E bolt	29000	ksi	young's modulus of elasticity				
F_t	19.14	ksi	allowable tension on bolt				
T bolt	25.61	k					
	d inches	# bolts		ratio	T kips	M k-in	
A	71.60	2	71.60	1.000	51.21	3667	
B	62.60	4	71.60	0.874	89.55	5606	
C	53.60	2	71.60	0.749	38.34	2055	
					sum M	11327	
				sum T	179.10		

row 120

C	181.2	k	120.8 * 0.750 * 2 base plates compression/bearing block
	101.2%	convergence	
M_{ot}	1045.0	k-ft	overturning moment
W	148.05	k	weight to resist overturning
M_{rt}	450.3	k-ft	righting moment
M_net	594.7	k-ft	required 1,045.0 k-ft - 450.3 k-ft
M bolts	943.9	k-ft	provided
$T_{bolt\ reqd}$	**16.1**	**K**	**594.7 /943.9 * 25.61 k**

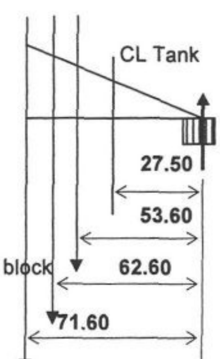


Figure 24-6 Diagram of bolt strain.

row 130

A B C D E F G H I J K L M N
BOLT THREADS

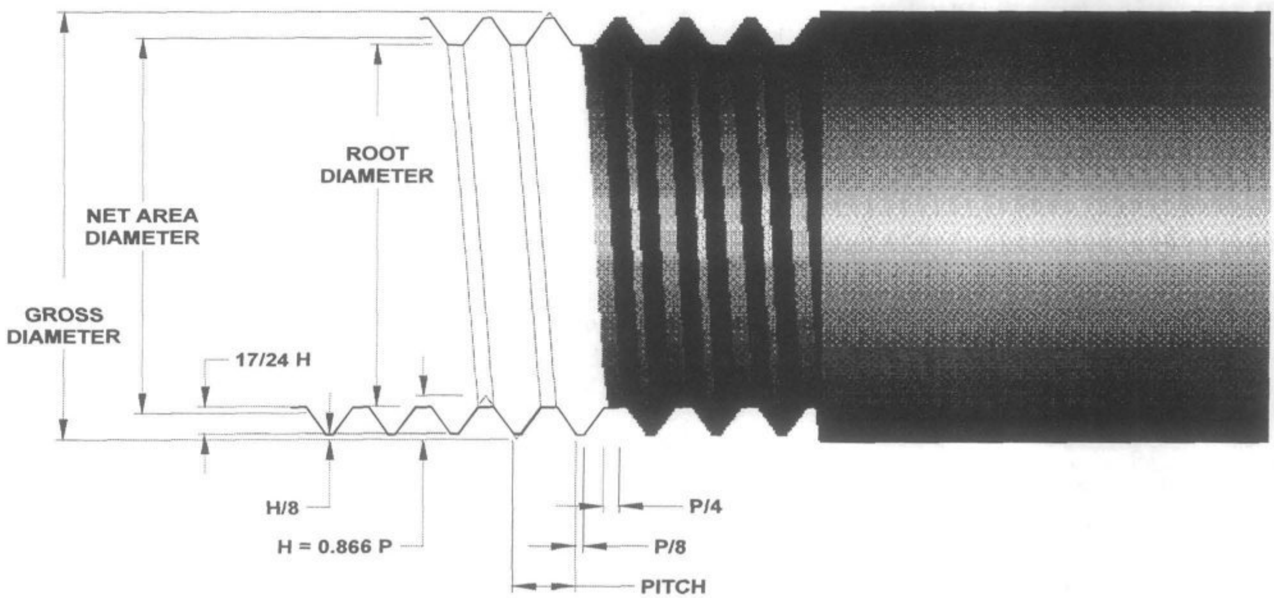
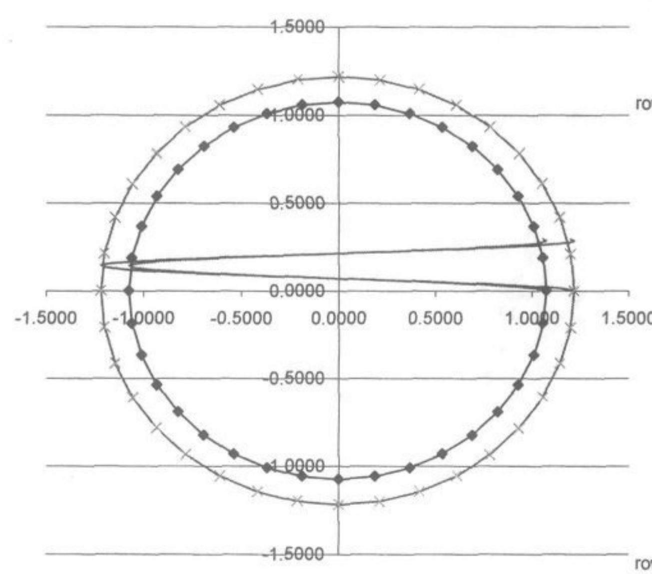


Figure 25-1 Bolt threads and bolt body.

row 40

Reference: AISC 9th Edition Part 4 - 3 tension on gross area
Section J - 3, page 5 - 72 and some common sense
American Institute of Steel Construction (AISC)

D	**1.2500**	in	
D threads	1.2191	in	
n	**7**	threads/inch	
pitch	0.1429	in	distance between threads
H	0.1237	in	0.866 P
H/6	0.0206	in	
H/8	0.0155	in	
K root	1.0747	in	diameter to thread roots
A tensile	0.9691	in^2	
D tensile	1.1108	in	
pitch_angle	2.2785	degrees	



row 50

row 70

Figure 25-3 The thread cross-section.

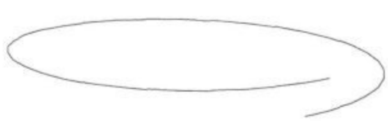


Figure 25-2 The bolt thread spiral from an AUTOCad DRAWING.

You will note that this manual contains only examples and templates.
There are no problems or example problems, just opportunities to do engineering and make a living.

row 80

BOLT THREADS
Threads versus Strength of Bolt
EXHAUST STACK

A B C D E F G H I J K L M N

BOLT STRENGTH

Shear Across Bolt

D	**1.25**	in	gross diameter
n	**7**	count	number of threads per inch
Grade	**A354 Gr. BD**	type	AISC Values
F_t	54	ksi	F_u * 0.33
A gross	1.227	in^2	π * (D /2)² 3.14 * (1.250 /2)²
V gross	**66.3**	**k**	on gross section of bolt 54 * 1.227
A threads	0.969	in^2	=0.7854*(D - 0.9743 /n)² 0.7854 * (1.250 - 0.9743 /7)²
V threaded	**52.3**	**k**	at threaded portion of bolt 54 * 0.969

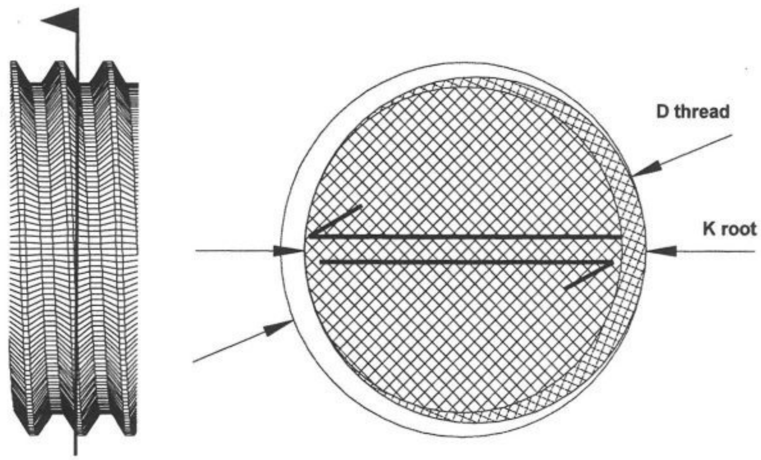


Figure 25-4 This is a cut through an elevation and the resulting section showing the area of the thread(s).

BOLT GRADE VALUES

Grade		F_y yield	F_u ultimate	Calculated Values F_t	F_v=0.17F_u threads in plane	F_v=0.22F_u	*AISC Values* F_t	F_v *threads in plane*	F_v *gross*	
A36		36	58	19.14	9.86	12.76	***19.1***	***9.9***	***12.8***	carbon steel with/without head
A307			60	19.8	10.2	13.2	***20***	***10***	13.2	carbon steel with head
A325	to 1" Grade 5, B7	92	120	39.6	20.4	26.4	***44***	***21***	***30***	carbon,
A325-1	1 1/8" to 1 1/2"	81	105	34.65	17.85	23.1	***44***	17.9	23.1	carbon,
A490	Grade 8, 1/2" to 1 1/2"	120	150	49.5	25.5	33	***54***	***28***	***40***	alloy,
A354 Gr. BD	1/2" to 2 1/2"	120	150	49.5	25.5	33	***54***	***28***	***40***	alloy, quenched & tempered steel with/without head
AISI 304 SS		65	100	33	17	22				stainless steel

row 110

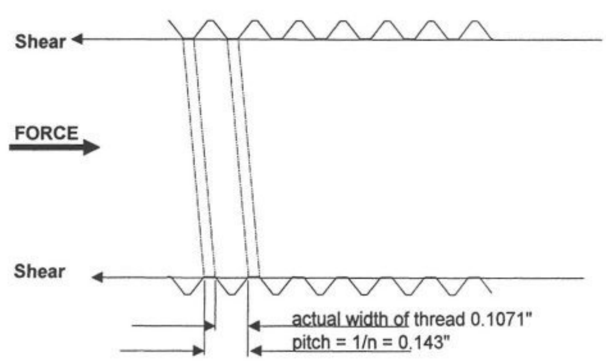
row 120

A36 can be purchased at the hardware store as allthread rod.
A354 Grade BD is usually specified as interchangeable with A490 bolts. A354 Gr. BD is often furnished as a high-strength anchor bolt and is also used in high temperature conditions, like your car engine's head bolts.

head	bolt head
n	number of threads

Values Calculated per the AISC Ninth Edition -- Thread Stripping Shear

Grade	**A325**	type	AISC Values
F_t	44	ksi	tension
F_v	21	ksi	shear through threads in plane
D gross	**1.25**	in	gross diameter of bolt
n	**7**	threads/inch	
H	0.124	in	
K root	1.075	in	least diameter
w thread	0.1071	in	actual width of thread pitch - pitch/4
F/thread	5.698	k/thread	Fv * area of thread in shear 21 ksi * 0.75 * 0.1071 inch* 1.075 in * π
Threads	**7**	n	threads provided
T threads	39.88	k	7 threads * 5.698 k
T gross	54.00	k	A gross * F_t 1.227 * 44
T threads	42.64	k	A threads * F_t 0.969 * 44



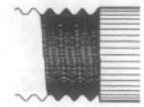
row 130

row 140

Figure 25-5 Stripping shear through the bolt threads.

row 150

BOLT THREADS
Threads versus Strength of Bolt
EXHAUST STACK



A B C D E F G H I J K L M N

SUMMARY

Diameter	1.2500	in	gross diameter
n	7	count	number of threads per inch
Grade	A325		
F_t	44	ksi	tension
F_v	21	ksi	shear

Thread Stripping Shear

Threads	7	n	threads provided
T stripping	39.88	k	stripping capacity

Bolt Tension

T gross	54.00	k	on gross section of bolt
T threads	42.64	k	at threaded portion of bolt

Shear Across Bolt

V gross	66.3	k	on gross section of bolt
V threaded	52.3	k	at threaded portion of bolt

Loads

T required	**35.60**	k	
V required	**1.38**	k	**sum of wind pressure at 35.6 mph during vortex shedding**

COMBINED LOADS FOR THE UNITY EQUATION

For Shear and Tension on Threaded Portion of the Bolt

T governs 39.88 k min(39.88, 42.64)

Parabolic Curve

Tension		Shear		Sum
$(35.60 / 39.88)^2$	+	$(1.4 / 52.3)^2$	=	0.797 + 0.001
0.797	+	0.001	=	0.797

Straight Line

(35.60 /39.88)	+	(1.4 /52.3)	=	0.893 + 0.026
0.893	+	0.026	=	0.919

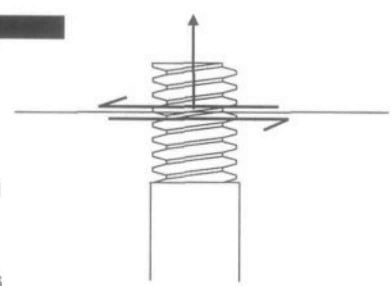


Figure 25-6 Tension and shear through the bolt threads.

For Shear Through the Unthreaded Portion of the Bolt and Tension on Threaded Portion of the Bolt

Parabolic Curve

Tension		Shear		Sum
$(35.60 / 39.88)^2$	+	$(1.4 / 66.3)^2$	=	0.797 + 0.000
0.797	+	0.000	=	0.797

Straight Line

(35.60 /39.88)	+	(1.4 /66.3)	=	0.797 + 0.021
0.797	+	0.021	=	0.818

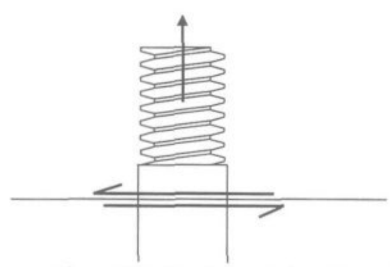


Figure 25-7 Tension and shear through the bolt body.

A B C D E F G H I J K L M N

BOLT THREADS AISC Ninth Edition First Printing (7/89)

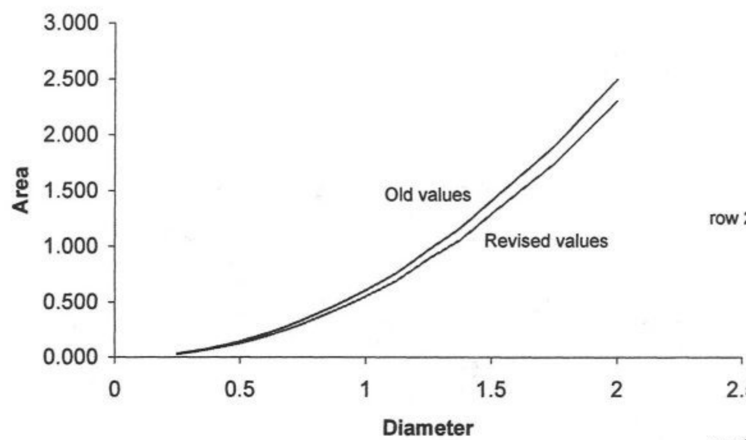
Diameter bar stock inch	Area Root K inch	Gross A_D in²	Root A_K in²	Tensile Stress in²	Threads per inch n	Pitch in	F_t tension on gross (nominal) k	F_t tension on threaded (net area) k	Thread Shear Plane length in	F_v * area of thread in shear plane k	Ft/ thread per thread Threads Required n	length required inch	H in
1/4	0.189	0.0491	0.027	0.032	20	0.050	2.16	1.18	0.0375	0.351	6.16	0.308	0.043
3/8	0.298	0.1104	0.068	0.077	16	0.063	4.86	2.98	0.0469	0.691	7.03	0.439	0.054
1/2	0.406	0.1963	0.126	0.142	13	0.077	8.64	5.53	0.0577	1.159	7.45	0.573	0.067
5/8	0.514	0.3068	0.202	0.226	11	0.091	13.5	8.88	0.0682	1.734	7.78	0.708	0.079
3/4	0.627	0.4418	0.302	0.334	10	0.100	19.4	13.3	0.0750	2.327	8.35	0.835	0.087
7/8	0.739	0.6013	0.419	0.462	9	0.111	26.5	18.4	0.0833	3.047	8.68	0.965	0.096
1	0.847	0.7854	0.551	0.606	8	0.125	34.6	24.2	0.0938	3.929	8.80	1.099	0.108
1 1/8	0.950	0.994	0.693	0.763	7	0.143	43.7	30.5	0.1071	5.036	8.68	1.241	0.124
1 1/4	1.075	1.227	0.890	0.969	7	0.143	54.0	39.1	0.1071	5.699	9.47	1.354	0.124
1 3/8	1.171	1.485	1.054	1.155	6	0.167	65.3	46.4	0.1250	7.243	9.02	1.503	0.144
1 1/2	1.296	1.767	1.294	1.405	6	0.167	77.8	56.9	0.1250	8.016	9.70	1.617	0.144
1 3/4	1.505	2.405	1.744	1.899	5	0.200	105.8	76.7	0.1500	11.170	9.47	1.895	0.173
2	1.727	3.142	2.300	2.498	4.5	0.222	138.2	101.2	0.1667	14.242	9.71	2.157	0.192

Comparison of Published and Calculated Threaded Areas

Values in the AISC Ninth Edition, First Printing (7/89) vary from the formula 0.7854*(D -1.3 /n)² for the root area AK. The difference between the first and second AISC printings is shown below and in the graph. ICE calculations equal the revised AISC values.

row 250

Diameter bar stock inch	Threads per inch n	AISC ICE A_K in²	AISC 1st ed (7/89) A_K in²	% difference
0.25	20	0.027	0.032	**16.0**
0.375	16	0.068	0.078	**13.1**
0.5	13	0.126	0.142	**11.5**
0.625	11	0.202	0.226	**10.7**
0.75	10	0.302	0.334	**9.6**
0.875	9	0.419	0.462	**9.3**
1	8	0.551	0.606	**9.1**
1.125	7	0.693	0.763	**9.2**
1.25	7	0.890	0.969	**8.2**
1.375	6	1.054	1.16	**9.2**
1.5	6	1.294	1.41	**8.3**
1.75	5	1.744	1.90	**8.2**
2	4.5	2.300	2.50	**8.0**



row 260

Figure 25-8 VERIFICATION GRAPH

row 270

The diagram shown in the AISC Ninth Edition and previous editions is inaccurate. The gross diameter of the bolt threads is never as great as the bolt stock from which they were cut or rolled.

row 280

row 290

A B C D E F G H I J K L M N

BOLT GRADES

A354 Grade BD bolt stock is the same as
A490 headed bolts and
SAE Grade 8 bolts

Threaded bolt stock may be marked **BD** or with the six spoke symbol.

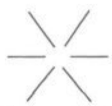
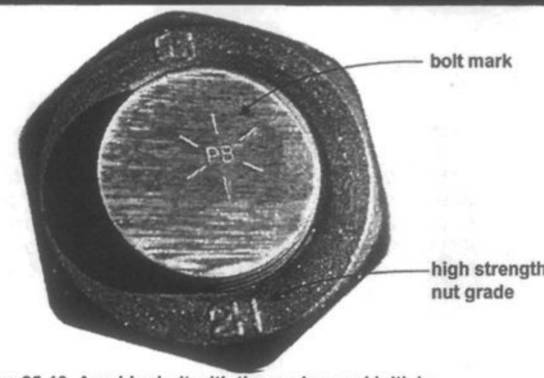


Figure 25-9 The old bolt mark for Grade BD bolts.



row 300

Figure 25-10 An older bolt with the spokes and initials representing Portland Bolt Company.

row 310

STEEL GRADES

Steels	Grade	Yield	Tensile Range	
A36		36	58 - 80	carbon steel
A53		35	60 min	
A500	A	33	45 min	
A500	B	42	58 min	
A501		36	58 min	
A529	50, 55	42	60 - 85	carbon steel
A572	42	42	60 min	high strength, low alloy
A572	50	50	65 min	
A588	< 4"	50	70 min	high strength, low alloy
A709	36	36	58 - 80	
A709	50	50	65 min	
A709	50W	50	70 min	
A913	50	50	65 min	
A992		50	65	

row 320

ASTM established A992 in 1998 to replace/upgrade A36 and A572 grade 42 and is commonly provided in lieu of A36.

A992 is produced in the US from recycled steel and scrap in arc furnaces.

Bolt to be Installed

row 330

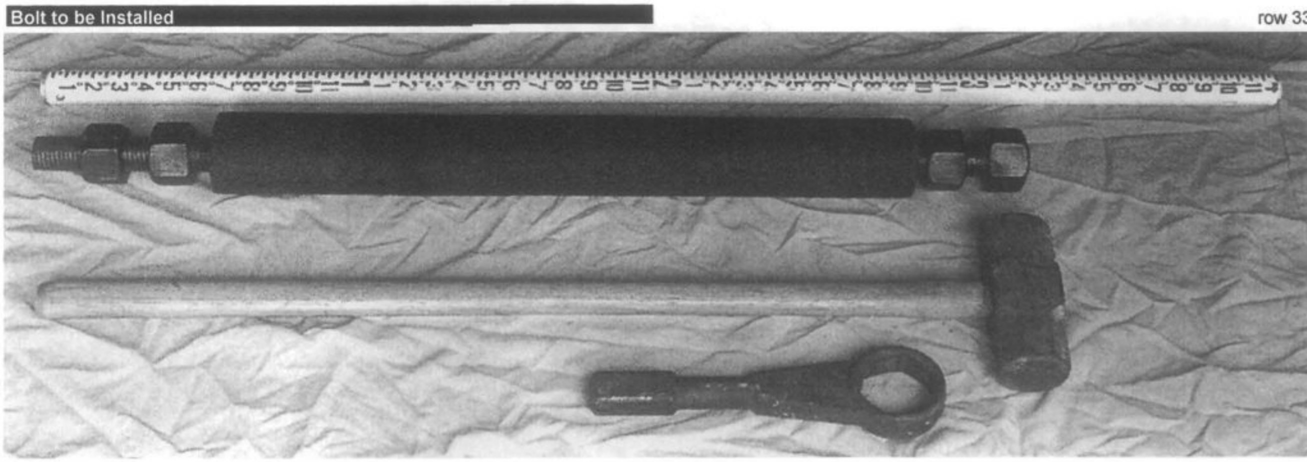


Figure 25-11 The 1 1/2" Ø bolt in an epifoam insulation sleeve is shown here with a 10 Lb. hammer and hit wrench. The surveyor's rod is used for reference. row 350

Epifoam sleeves, pipes, and plastic pipes are used to prevent concrete bond with the bolt. This allows bolt stretch during impact events. The bolt can be pretensioned with the hit wrench or a large impact hammer. Calculate the turn of the nut versus the length of the bolt between the nuts.

row 360

A B C D E F G H I J K L M N

GRAPHING RANGES

			K root diameter			D threads		
Sine	Cosine		x	y	z	x	y	z
0	1	0	1.0747	0.0000	0.0000	1.2191	0.0000	0.0000
0.1736482	0.9848078	1	1.0584	0.1866	0.0079	1.2006	0.2117	0.0079
0.3420201	0.9396926	2	1.0099	0.3676	0.0159	1.1456	0.4169	0.0159
0.5	0.8660254	3	0.9308	0.5374	0.0238	1.0557	0.6095	0.0238
0.6427876	0.7660444	4	0.8233	0.6908	0.0317	0.9339	0.7836	0.0317
0.7660444	0.6427876	5	0.6908	0.8233	0.0397	0.7836	0.9339	0.0397
0.8660254	0.5	6	0.5374	0.9308	0.0476	0.6095	1.0557	0.0476
0.9396926	0.3420201	7	0.3676	1.0099	0.0556	0.4169	1.1456	0.0556
0.9848078	0.1736482	8	0.1866	1.0584	0.0635	0.2117	1.2006	0.0635
1	6.126E-17	9	0.0000	1.0747	0.0714	0.0000	1.2191	0.0714
0.9848078	-0.173648	10	-0.1866	1.0584	0.0794	-0.2117	1.2006	0.0794
0.9396926	-0.34202	11	-0.3676	1.0099	0.0873	-0.4169	1.1456	0.0873
0.8660254	-0.5	12	-0.5374	0.9308	0.0952	-0.6095	1.0557	0.0952
0.7660444	-0.642788	13	-0.6908	0.8233	0.1032	-0.7836	0.9339	0.1032
0.6427876	-0.766044	14	-0.8233	0.6908	0.1111	-0.9339	0.7836	0.1111
0.5	-0.866025	15	-0.9308	0.5374	0.1190	-1.0557	0.6095	0.1190
0.3420201	-0.939693	16	-1.0099	0.3676	0.1270	-1.1456	0.4169	0.1270
0.1736482	-0.984808	17	-1.0584	0.1866	0.1349	-1.2006	0.2117	0.1349
1.225E-16	-1	18	-1.0747	0.0000	0.1429	-1.2191	0.0000	0.1429
-0.173648	-0.984808	19	-1.0584	-0.1866	0.1508	-1.2006	-0.2117	0.1508
-0.34202	-0.939693	20	-1.0099	-0.3676	0.1587	-1.1456	-0.4169	0.1587
-0.5	-0.866025	21	-0.9308	-0.5374	0.1667	-1.0557	-0.6095	0.1667
-0.642788	-0.766044	22	-0.8233	-0.6908	0.1746	-0.9339	-0.7836	0.1746
-0.766044	-0.642788	23	-0.6908	-0.8233	0.1825	-0.7836	-0.9339	0.1825
-0.866025	-0.5	24	-0.5374	-0.9308	0.1905	-0.6095	-1.0557	0.1905
-0.939693	-0.34202	25	-0.3676	-1.0099	0.1984	-0.4169	-1.1456	0.1984
-0.984808	-0.173648	26	-0.1866	-1.0584	0.2063	-0.2117	-1.2006	0.2063
-1	-1.84E-16	27	0.0000	-1.0747	0.2143	0.0000	-1.2191	0.2143
-0.984808	0.1736482	28	0.1866	-1.0584	0.2222	0.2117	-1.2006	0.2222
-0.939693	0.3420201	29	0.3676	-1.0099	0.2302	0.4169	-1.1456	0.2302
-0.866025	0.5	30	0.5374	-0.9308	0.2381	0.6095	-1.0557	0.2381
-0.766044	0.6427876	31	0.6908	-0.8233	0.2460	0.7836	-0.9339	0.2460
-0.642788	0.7660444	32	0.8233	-0.6908	0.2540	0.9339	-0.7836	0.2540
-0.5	0.8660254	33	0.9308	-0.5374	0.2619	1.0557	-0.6095	0.2619
-0.34202	0.9396926	34	1.0099	-0.3676	0.2698	1.1456	-0.4169	0.2698
-0.173648	0.9848078	35	1.0584	-0.1866	0.2778	1.2006	-0.2117	0.2778
-2.45E-16	1	36	1.0747	0.0000	0.2857	1.2191	0.0000	0.2857
0.1736482	0.9848078	37	1.0584	0.1866	0.2937	1.2006	0.2117	0.2937

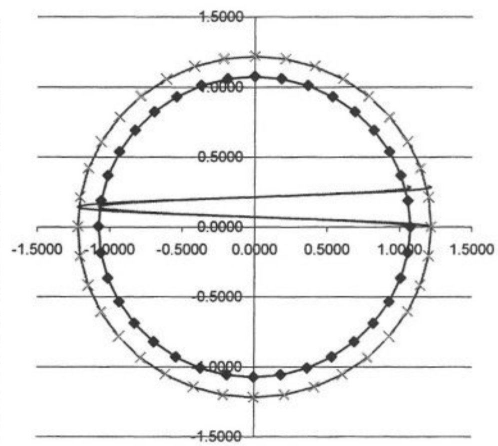


Figure 25-12 This is a graph of bolt threads relative to the gross round-bar stock diameter and thread pitch.

row 390

row 400

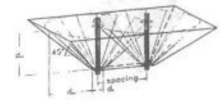
row 410

row 420

row 430

BOLT GROUP PULLOUT INTRODUCTION
EXHAUST STACK

Not included on the CD-ROM



ENGINEERING with the SPREADSHEET

26 Bolt Group Pullout Introduction.xls

A B C D E F G H I J K L M N

ANCHORING IN CONCRETE

This chapter presents two approaches to bolting in concrete.

The first method uses the shear-friction method where the bolt clamps the steel base plate against the supporting concrete surface. This is useful in tank and equipment bolting though steel or plywood positioning templates are used to locate the bolt projection through the concrete.

Isolate the bolt from the concrete with a pipe insulation sleeve or length of pipe. This allows the bolts to be pushed sideways to get them up through the bolt holes.

row 20

This method has the additional advantage of allowing the bolt to stretch along its length during a seismic event or mishap with a truck or a forklift.

After the concrete cures, say seven days, the nut should be brought to hand tight and then turned about 1/4 thread of a turn to prestress the bolt and add in clamping. The amount of turn should be calculated. The turn will have to be done with a hit-wrench or impact hammer.

row 30

The plate serves as the anchor -- not the shank of the bolt. Calculate the plate in punching shear. Reduce the shear cone for anchor bolts placed closely together.

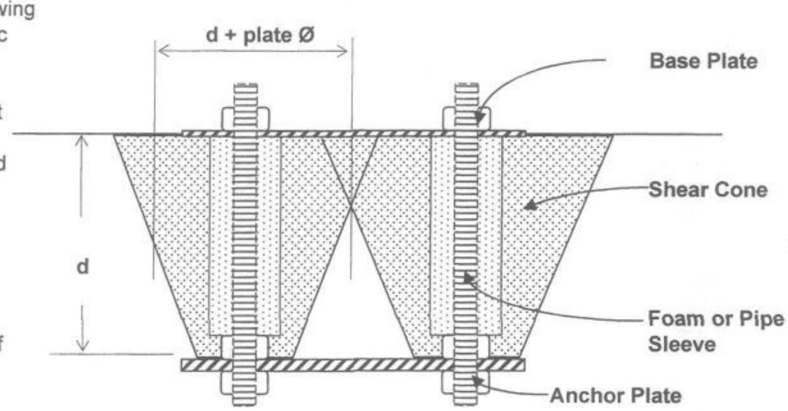


Figure 26-1 Elevation of punching shear cones.

The second method is the '97 UBC bolt group calculation.

row 40

This is intended more for a group of headed weld studs in an anchor plate. This method uses the projected area on the surface of the concrete to calculate the effect of the group.

This method has been revised in the 02 ACI 318 appendix D.

row 50

Where anchor spacing is greater than 2 * d_m calculate the anchorage with the value of a single anchor * number of anchors.

Refer to page 262 of SEISMIC DESIGN OF BUILDINGS and *BRIDGES by Alan Williams, PE, published by the* Engineering Press

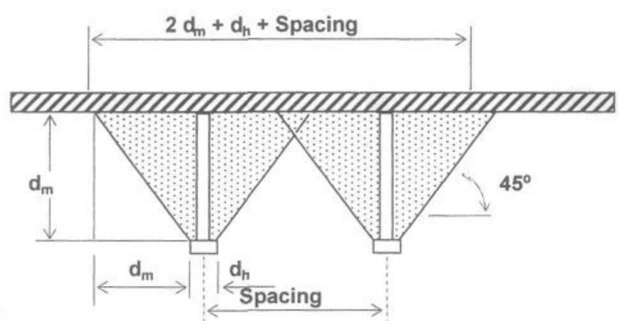


Figure 26-2 Elevation of anchor group shear cones.

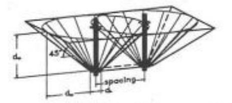
row 60

At the end of this chapter is a parsing of Code language. This amounts to an argument against text only explanations of engineering concepts.

The 02 ACI presents code language, a running commentary, and diagrams. This is preferable to the text only presentation which can be interpreted a number of ways. Comprehensive presentations expose themselves to an uncovering, so-to-speak, of errors in reasoning. However, I feel that the ACI presentation is preferable.

row 70

Vortex moment and shear govern

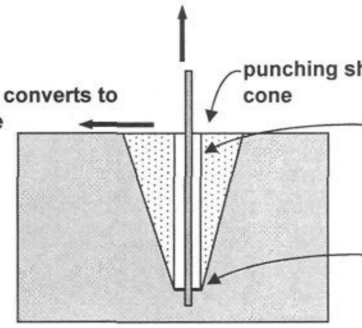


A B C D E F G H I J K L M N

SHEAR FRICTION CONNECTION -- PUNCHING SHEAR UBC 1911.7

This design uses the anchor bolt to clamp the steel baseplate down onto the concrete slab/foundation. After grouting beneath the base plate, the bolt is tensioned by tightening the nut -- usually about 1/4 turn of the nut.

Lateral loads are converted to bolt tension loads via the concept of shear friction. Bolt lateral capability is factored down with the factors λ *and* μ *which account for a steel plate trying to slide on* concrete.



row 20

Figure 27-1 Converting lateral force to tension force.

Force per Turn-of-the-Nut

d	21.0	in	
threads	5	threads/inch	
Dia	1.75	in	
turn	0.125	turn of nut 45degrees	

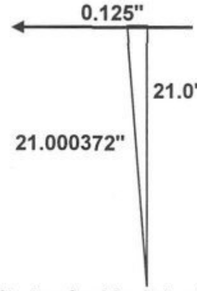
row 30

stretch	0.025000	inch	0.125 turn /5 threads/inch
strain	1.001190	inches/inch	(d + stretch) / d (21.0" + 0.025000") / 21.0"
E_S	29000	k/in^2	Young's modulus for steel
A_{bolt}	2.41	in^2	$(1.75"/2)^2 * \pi$ gross area of the bolt
force	83.04	k	E_S * A_{bolt} * (strain - 1) 29,000 ksi * 2.41 in² * (1.001190 - 1)

row 40

Force per Lateral Movement

displace	0.125	inch	
lengthen	21.000372	inch	$\sqrt{21.0^2 + 0.125^2}$
force	25.95	k	(lengthen - d) * E_S * A_{bolt} (21.000372 - 21.0) * 29,000 ksi * 2.41in²



row 50

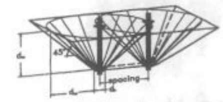
Figure 27-2 Bolt streched by lateral displacement.

row 60

row 70

BOLT GROUP PULLOUT
EXHAUST STACK

Vortex moment and shear govern



A B C D E F G H I J K L M N

SHEAR FRICTION CONNECTION -- Strength of Bolt

Dia	**1.75** in			μ	UBC 1911.7.4.3
Grade	**A325** grade			**1.4**	monolithic concrete
				1.0	concrete placed against roughened-hardened concrete
T_tens	**35.60** k	required tension		**0.6**	against un-roughened hardened conc.
V_shear	**1.38** k	required shear		**0.7**	against as-rolled structural steel
μ	**0.7** unitless	concrete roughness factor		λ	UBC 1911.7.4.3
λ	**1.00** unitless	concrete weight factor		**1.00**	normal weight concrete (row 80)
				0.85	sand light weight concrete
				0.75	all-light weight concrete

logic				1	2	3	4	5	6	7	8	9	0
Diameter	F_v	F_u	F_t	0.625	0.75	0.875	1	1.125	1.25	1.375	1.5	1.75	2
n = Threads/inch			$F_t = F_u/3$	11	10	9	8	7	7	6	6	5	4.5
A Tensile Stress				0.226	0.334	0.462	0.606	0.763	0.969	1.155	1.405	1.899	2.498
$0.7854 *(D\ Gross - 0.9743/n)^2$													
Area_b	$p * r^2$			0.307	0.442	0.601	0.785	0.994	1.227	1.485	1.767	2.405	3.142
A36	36	58	**19.1**	5.86	8.44	11.49	15.00	18.99	23.44	28.36	33.75	45.94	60.00
A307			**20**	6.14	8.84	12.03	15.71	19.88	24.54	29.70	35.34	48.11	62.83
A325	Grade 5		**44**	13.50	19.44	26.46	34.56	43.74	54.00	65.34	77.75	105.8	138.23
B7	Grade 5		**44**	13.50	19.44	26.46	34.56	43.74	54.00	65.34	77.75	105.8	138.23
A490	Grade 8	A354 GR BD	**54**	16.57	23.86	32.47	42.41	53.68	66.27	80.18	95.43	129.9	169.65

VLookUp	44 ksi	allowable F_t from the lookup table below
Area_bolt	2.405 in^2	Gross (nominal) area per AISC Part 4 Connections Tables 1-A and 1-B

row 100

T_allow	105.83 k	F_t * Area_bolt
V_allow	30.80 k	T_allow * m * l UBC 1911.7.4.1
		105.83 k * 0.70 * 1.00

T_tens/T_allow	+	V_shear/V_allow	= UBC 1923.1 Unity		
35.60 / 105.83		1.38 / 30.80	= 0.336 + 0.045 =	**0.381**	< 1.333 OK
0.336		0.045			

logic 1

row 110

Refer to the **Bolt Threads** chapter in this manual for bolt values.

These values are taken from **AISC Table 1-A BOLTS, THREADED PARTS AND RIVETS** and **Table 1-B THREADED FASTENERS** where values for F_t are multiplied by the gross area to get allowable loads. See **Gaylord and Gaylord 2nd edition** page 6-79 for an example.

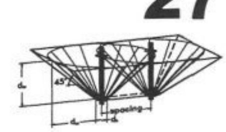
row 120

Tensile strength may also be obtained from **AISC Table 1-C MATERIAL FOR ANCHOR BOLTS AND TIE RODS**. Allowable loads are generated by multiplying the tensile strength by the Tensile Stress Area given in **Table ANSI B1.1-1982** on page 4-147 of 9th edition of the **AISC ASD** manual. The Tensile Stress Area accounts for available area reduced by the presence of bolt threads.

row 130

BOLT GROUP PULLOUT
EXHAUST STACK

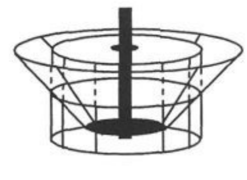
Vortex moment and shear govern



A B C D E F G H I J K L M N

SHEAR FRICTION CONNECTION -- Base Plate Sliding / Shear Plane

T_tens	**35.60**	k	required tension
V_shear	**1.38**	k	required shear
f'_c	**3**	k/in^2	
A_c	**100**	in^2	shear area A_C (base plate or shear plane)
f_y	**132**	k/in^2	specified yeild strength $= F_u$ tensile for bolt material
A_{st}	**2.405**	in^2	bolt area A_{vf}
μ	**0.7**	unitless	UBC 1911.7.4.3
V_n	222.2	k ult	$A_{vf} * f_y * \mu$ UBC (11-25)
Limited by			
V_n	60.0	k ult	$0.2 * f'_C * A_C$ UBC 1911.7.5
V_n	80.0	k ult	$800 * A_C$
V_n	**60.0**	k ult	



row 140

Figure 27-3 Single anchor punching shear cone.

Punching Shear

d	**21.0**	in	embed depth to top of anchor plate
PL_dia	**3.0**	in	plate diameter
b_o	75.4	in	at d/2 from edge if anchor plate [(d /2) * 2 + PL_diameter] * p (21.0 + 3.0) * PI
V_C	347	k ult	$4\sqrt{f'_C} * b_o * d$ UBC (11-37) where $b_o * d = A_o$ 4 * (3 * 1000)^0.5 * 75.4 * 21.0 /1000
Φ	0.85	unitless	strength reduction factor
V_u	**294.9**	k_ult	
P allowed	60.0	k ult	minimum of 294.9, 80.0, 60.0, 222.2
P allowed	**42.9**	k working	60 k_ult / 1.4 UBC (12 - 11) basic load combinations
λ	**1**	unit	UBC 1911.7.4.3
Tu_sum	**37.6**	k_ult	factor * (t_tens + V_shear /(μ * λ)) UBC 1911.7.4.3 1.0 * (35.60 + 1.38 / (0.70 * 1.00))
T_sum	**37.6**	k	Tu_sum / (factor = 1.00) for working strength
	42.9 > 37.6 required	OK	

row 150

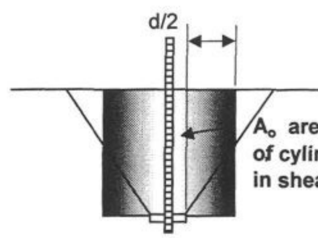


Figure 27-4 Punching shear cylinder.

SHEAR FRICTION CONNECTION -- Bearing Against Anchor Plate

Area of bearing must be at least 1.5 x anchor shank area 1923.3.4

Diameter	**1.75**	in	
A shank	2.41	in^2	
factor	**1.0**		seismic factor UBC1612.2.1 (12-5) / UBC 1909.2.3
μ	**0.7**	unit	UBC 1911.7.4.3
λ	**1**	unit	UBC 1911.7.4.3
A_1	**18.10**	in^2	gross area of plate (square or round)
A_1 net	16	in^2	A_1 net - A shank
		OK Area	
A_2	**600**	in^2	area of supporting surface which is wider on all sides than the bearing area
area_mult	2.0		$\sqrt{A\_2/A\_1}$ not to exceed 2.0 MIN(2, (600 /16)^0.5)
Φ_bearing	**0.9**	factor	UBC 1909.3.2.4 Φ = 0.70 or UBC 1918.13.4 for post tensioned concrete = 0.90
f'_C	**3**	k /in²	
T_allow	138.43	k	Φ_bearing * (0.85 * f'c * A_1 net) * area_mult
		OK.	0.90*(0.85 * 5 * 18) * 2.0

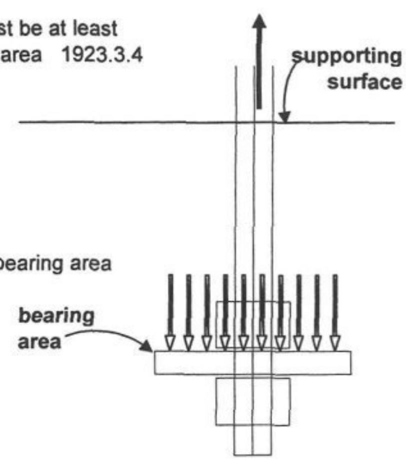
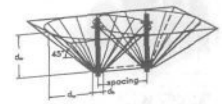


Figure 27-5 Concrete bearing against the anchor plate.

q_plate	2.395	k /in²	Tu_sum / A_1 net for plate design
			OK q_concrete bearing allowed = 2.700 ksi

row 190



A B C D E F G H I J K L M N

ANCHORAGE TO CONCRETE, Tension -- Fully Encased Bolt UBC 1923.2

Inspect	**1.3**	unitless	inspection factor
T_tens	**0.00**	k_ult	required tension /bolt - ultimate
V_shear	**11.40**	k_ult	required shear /bolt - ultimate
P_u	**0.0**	k_ult	tension
V_u	**14.8**	k_ult	shear
d bolt	**0.75**	in	anchor shank diameter
A_b	0.44	in^2	net cross-section area of bolt
d_e	**10**	in	edge distance **toward** loaded edge
Edge 2	**3**	in	edge distance **away** from loaded edge
	1	logic	
	0	logic	
Edge	0	logic	
f_{ut}	**58**	k/in^2	bolt ultimate tensile strength
P_{ss}	**23.1**	k_ult	$0.9 * A_b * f_{ut}$ 0.9 * 0.44 in² * 58 ksi
V_{ss}	**19.2**	k_ult	$0.75 * A_b * f_{ut}$ 0.75 * 0.44 in² * 58 ksi
λ	**1.00**	unitless	concrete factor
d_h	**1.25**	in	Tributary area of plate 1.2 in² or head Actual plate may be rectangular
d_m	**5.0**	in	depth of embedded plate for pullout
f'_c	**3**	k/in^2	compressive strength of concrete
A_P	99	in^2	effective area of projected cone onto the surface of the slab ((1.3 + 2 * 5.0) /2)² * π
P_c	**5.4**	k_ult	$\lambda * A_P * \sqrt{f'_C}$ UBC 1923.3.2 $1.00 * 99\ in^2 * \sqrt{3{,}000}\ /1000$
V_c	19.4	k_ult	$800 * A_b * \sqrt{f'_C}$ UBC 1923.3.3 $800 * 0.44 * \sqrt{3 * 1000}\ /1000$ for bolts more than 10 diameters towards the loaded edge V_c not governed by A_b
V_c	34.4	k_ult	$2\,\pi\, d_e^2\, \lambda\, f'_C$ $2 * \pi * 10.0^2 * 1.00 * \sqrt{3 * 1000}\ /1000$
V_c	**34.4**	k_ult	
Φ	**0.85**	unitless	0.85 for confined anchor embedment 0.65 for unconfined anchor embedment UBC 1923.3.2 execption

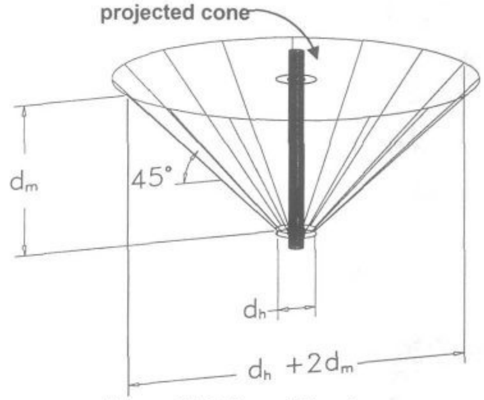


Figure 27-6 View of the shear cone.

row 200

INSPECTION -- UBC 1923.2 row 210

1.3 Special inspection provided for bolts anchored in compression zone
2 No special inspection
2 Special inspection provided for bolts anchored in tension zone
3 No special inspection for bolts anchored in the tension zone

λ UBC 1923.3.2 row 220

1.00 normal weight concrete
0.85 sand light weight concrete
0.75 all-light weight concrete

Edge distance

Shear loading more than 10 diameters from the loaded edge.

row 230

Tension or shear away from an edge more than 5 diameters away and with reinforcing to prevent concrete in tension failure.

Edge distance not less than 4 diameters in any case.

row 240

$$\frac{1}{\Phi}\left[\left[\frac{P_u}{P_c}\right]^{5/3}+\left[\frac{V_u}{V_c}\right]^{5/3}\right] = \frac{1}{0.85}\left[\frac{0.0}{5.4}^{5/3} + \frac{14.8}{34.4}^{5/3}\right] = \mathbf{0.289} < \mathbf{1.000\ OK}$$

$$\left[\frac{P_U}{P_{SS}}\right]^2 + \left[\frac{V_U}{V_{SS}}\right]^2 = \left[\frac{0.0}{23.1}\right]^2 + \left[\frac{14.8}{19.2}\right]^2 = \mathbf{0.595} < \mathbf{1\ OK}$$

row 250

ANCHORAGE TO CONCRETE, Tension -- Fully Encased Bolts in a Row UBC 1923.2

For a group of connectors, use the area of a truncated pyramid projected onto the surface of the slab

Rectangular area of projected pyramid

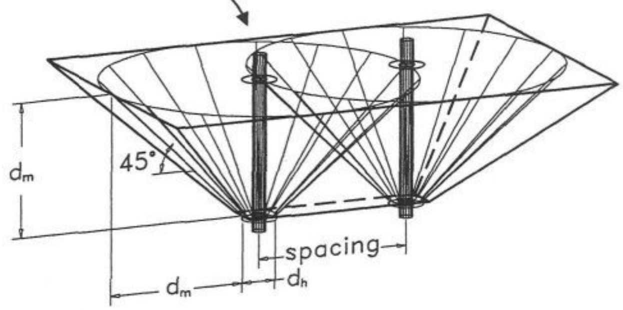


Figure 27-7 View of shear cones in a row.

P_u	**0.0** k_ult	tension	
V_u	**14.8** k_ult	shear	
spacing	**4.0** in	anchor spacing	
number	**5** unit	number of anchors	
	1 logic	OK 4.0 ≤ 2 * 5.0 Use Bolt Group	
P_{ss}	**115.3** k_ult	0.9 * A_b * f_{ut} * number 0.9 * 0.44 in² * 58 ksi * 5	
			row 270
V_{ss}	**96.1** k_ult	0.75 * A_b * f_{ut} * number 0.75 * 0.44 in² * 58 ksi * 5	
Length	27.25 in	2 * 5.0 dm + (4.0 spacing) * (5 number -1) + 1.25 dh	
Width	11.25 in	2 * 5.0 dm + 1.25 dh	
A_p	306.6 in²	Length * Width	
P_C	**16.8** k_ult	λ * A_p * $\sqrt{f'_c}$ UBC 1923.3.2 1.00 * 307 in² * 3,000 /1000	
			row 280
V_c	**172.1** k_ult	V_c * number 34.4 * 5	

$$\frac{1}{\Phi}\left[\left[\frac{P_U}{P_c}\right]^{5/3}+\left[\frac{V_U}{V_c}\right]^{5/3}\right] = \frac{1}{0.85}\left[\frac{0.0}{16.8}^{5/3} + \frac{14.8}{172.1}^{5/3}\right] = 0.020 < 1.000 \text{ OK}$$

$$\left[\frac{P_U}{P_{SS}}\right]^2 \left[\frac{V_U}{V_{SS}}\right]^2 = \left[\frac{0.0}{115.3}\right]^2 + \left[\frac{14.8}{96.1}\right]^2 = 0.024 < 1.000 \text{ OK}$$

row 290

HILTI		F_y	F_u	
HAS Std / A36		36	**58**	row 300
HAS Super /B7		105	**125**	
HAS SS /A 304 SS		65	**100**	
A307			**60**	
A108 studs			**60**	
A325	to 1" Grade 5, B7	92	**120**	
A325-1	1 1/8" to 1 1/2"	81	**105**	
A490	Gr 8, 1/2" - 1 1/2"	120	**150**	
A354 Gr. BD 1/2" to 2 1/2"		120	**150**	

row 310

CONSULTING COMPANY

BOLT GROUP PULLOUT

EXHAUST STACK

Vortex moment and shear govern

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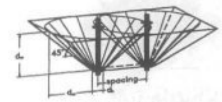


ENGINEERING with the SPREADSHEET

27 Bolt Group Pullout.xls

A B C D E F G H I J K L M N

ANCHORAGE TO CONCRETE, Tension -- Fully Encased Group of Bolts UBC 1923.2

For a group of connectors, use the area of a truncated pyramid projected onto the surface of the slab

This calculation was not a part of the stack calculation set.

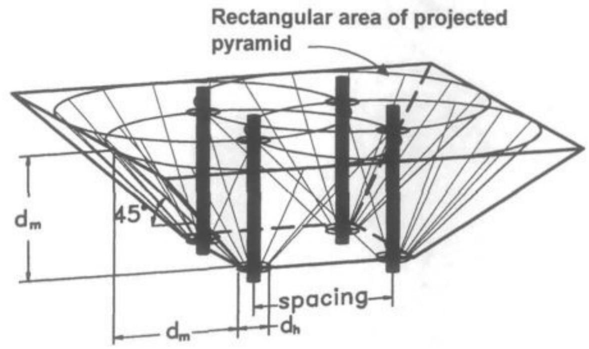


Figure 27-8 View of grouped shear cones.

P_u	**0.0**	k_ult	tension
V_u	**14.8**	k_ult	shear
spacing_	**4.0**	in	symetrical in both directions
number_	**4**	unit	4, 9, 16, 25, etcetera
	1	logic	OK 4.0 ≤ 2 * 5.0 Use Bolt Group
P_{ss}	**92.2**	k_ult	0.9 * A_b * f_{ut} * number_ 0.9 * 0.44 in² * 58 ksi * 4
V_{ss}	**76.9**	k_ult	0.75 * A_b * f_{ut} * number_ 0.75 * 0.44 in² * 58 ksi * 4
Length	15.25	in	2 * 5.0 dm + (4.0 spacing) *($\sqrt{4 \text{ number}}$ - 1) + 1.25 dh
Width	15.25	in	2 * 5.0 dm + (4.0 spacing) *($\sqrt{4 \text{ number}}$ - 1) + 1.25 dh
A_p	232.6	in^2	Length * Width
P_c	**12.7**	k_ult.	I * A_p * $\sqrt{f'_c}$ UBC 1923.3.2 1.00 * 233 in² * (3,000 ksi)^0.5
V_c	**137.7**	#REF!	V_c * number 34.4 * 4

row 330

row 340

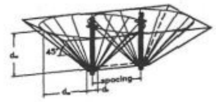
$$\frac{1}{\Phi}\left[\left[\frac{P_u}{P_c}\right]^{5/3}+\left[\frac{V_u}{V_c}\right]^{5/3}\right] = \frac{1}{0.85}\left[\frac{0.0}{12.7}^{\wedge 5/3} + \frac{14.8}{137.7}^{\wedge 5/3}\right] = \mathbf{0.029} \ \mathbf{< 1.000 \ OK}$$

$$\left[\frac{P_u}{P_{SS}}\right]^2 \left[\frac{V_u}{V_{SS}}\right]^2 = \left[\frac{0.0}{92.2}\right]^2 + \left[\frac{14.8}{76.9}\right]^2 = \mathbf{0.037} \ \mathbf{< 1.000 \ OK}$$

row 350

row 360

row 370



ANCHORAGE TO CONCRETE, Shear -- Fully Encased Bolt UBC 1923.3.3

PARSING UBC 1923.3.2 *WHERE*:

A_p = the effective area of the **projection**
of an assumed concrete failure surface
upon the surface from which the anchor protudes.

For a single anchor or for an anchor group
where the distance between anchors is equal to or greater than twice their embedment length, row 380
the surface is assumed to be that of a truncated cone
radiating at a 45 degree slope from the bearing edge of the anchor
toward the surface from which the anchor protrudes.

The effective area is the **projection** of the cone on this surface.

For an anchor which is perpendicular to the surface from which it protrudes,
the effective area is a circle.

For an anchor group where the distance between anchors is less than twice their embedment lengths, row 390
the failure surface is assumed to be that of a truncated pyramid
radiating at a 45 degree slope from the bearing edge of the anchor group
toward the surface from which the anchors protrude.

The effective area is the **projection** of this truncated pyramid on this surface.

In addition, for thin sections with anchor groups,
the failure surface shall be assumed to follow the extension of this slope through to the far side rather than be truncated,
and the failure mode resulting in the lower value of FP_c shall control.

row 400

Do you really think that you can understand this without diagrams?

row 410

row 420

row 430

ROARK FLAT PLATES
EXHAUST STACK

FLAT CIRCULAR PLATES / CONSTANT THICKNESS Roark, 5th Edition Table 24 pg 334

Check plate bending with several models from Roark and Young page 334

a	**2.400**	in	radius to outer edge
b	**0.880**	in	radius to inner edge
r_o	**1.600**	in	radius to location of w
			APPROXIMATE RADIUS OF BOLT HEAD
P	**42.90**	k	**For allowable P allowed working calculated in the Bolt Group Pullout template**
trib length	10.05	in	**ALONG EDGE OF WASHER**
w	**4267**	lb/in	point load / circumference line load
q_uniform	**2371**	lb/in^2	uniformly distributed load
r_	**1.00**	in	radial location of evaluated quantity
t	**1.000**	in	thickness of plate
v	**0.285**	unit	poisson ratio
E	**29000**	ksi	Young's modulus of elasticity
r_o / r	1.600		

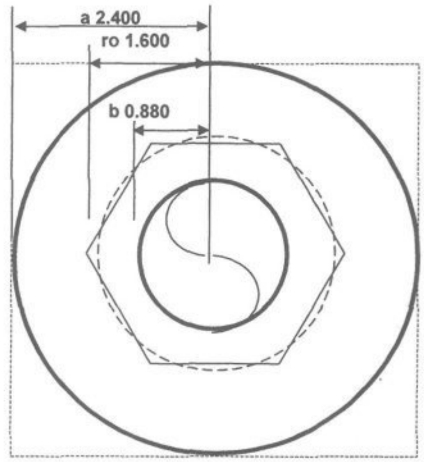


Figure 28-1 PLAN VIEW OF PLATE/WASHER

CONSTANTS..........................

C_1'	0.24	
	0.42	
C_1	0.658320	unit
C_2'	0.40	
C_2	0.148945	
C_3'	1.14	
C_3"	-0.87	
C_3	0.024992	
C_4	1.210583	
C_5	0.432778	
C_6'	1.14	
C_6	0.104596	
C_7	1.084433	unit
C_8'	0.10	
C_8	0.690564	
C_9'	0.64	
C_9"	0.15	
C_9	0.293091	
D	2630314	lb-in

D: plate constant
29,000 * 1.00^3 / (12 * (1 - 0.285^2)) * 1000 lb/k

G_3'	-1.67
G_3	0.0000
G_6'	0.62
G_6	0.0000
G_9'	-0.58
G_9	0.0000
L_3'	0.59
	-0.56
L_3	0.0050
L_6'	0.26
L_6	0.0426
L_9'	0.26
	0.10
L_9	0.2399
L_11'	1.79
L_11"	-4.35
L_11	0.0004
L_14'	0.80
L_14"	-0.72
L_14	0.0051
L_17'	0.86
L_17"	1.52
L_17	0.0451

F_1'	0.08	
F_1	0.13	
F_2'	0.97	
F_2	0.01	
F_4'	0.63	
F_4	0.72	
F_5	0.11	
F_6	0.01	
F_7	0.12	
F_9'	0.08	
	0.00	
F_9	0.07	
r r_o	0	logic

1.000 > 1.600 singularity factor

lb/in^2 = psi
k = 1000 Lbs.

row 20
row 30
row 40
row 50
row 60
row 70
row 80

A B C D E F G H I J K L M N

FLAT CIRCULAR PLATES / CONSTANT THICKNESS -- Continued

Roark Table 24, Case 2k: Outer edge free, inner edge simply supported... page 342

INPUTS FROM ABOVE

a	**2.400**	in	radius to outer edge
b	**0.880**	in	radius to inner edge
r_o	**1.600**	in	radius to location of w
q_uniform	**2371**	lb/in^2	uniformly distributed load
t	**1.00**	in	thickness of plate
v	**0.29**	unit	Poisson ratio
E	**29000**	ksi	Young's modulus of elasticity
y_b	0		per Roark
M_{ra}	*0*		per Roark
M_{rb}	0		per Roark
Q_a	0		per Roark
q_b'	-0.01149		=-q*(a^3)/(D*C7)
q_b''	0.22204		=(C_9/(2*A*B))*(A^2-RO^2)
q_b	-0.00255	radian	
Q_b	**4310**	lb/in	shear
			(Q_uniform / (2 * b)) * (a^2 - r_o^2)
			(2,371 /(2 * 0.880)) * (2.400^2 - 1.600^2)
y_a'	-0.0040		
y_a''	0.0006		
y_a'''	0.0000		
y_a	**-0.0035**	in	deflection
q_a'	-0.00309		
q_a''	0.00099		
q_a'''	0.00006		
q_a	-0.00216	radian	
r	**1.00**	in	radial location of quantity being evaluated -- input from above
M_t	-5231	lb-in/in	theta * D * (1 - v^2) /r + v * Mr
			-0.00216 * 2,630,314 * (1 - 0.285^2) /1.600 + 0.285 * 0
t	**1.0000**	in	from input above
S	0.16667	in^3	$1 * t^2 / 6$
f_b	**-31**	k/in^2	M_t / S

not used in this analysis

row 90

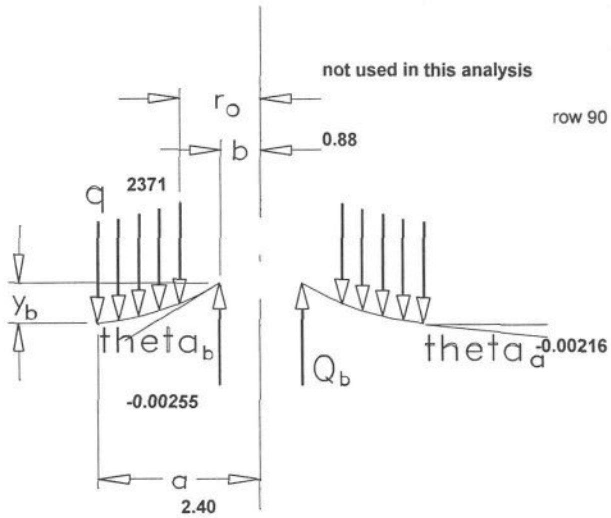


Figure 28-2 PLATE LOADING AND DEFLECTION

row 110

Q	unit shear	lb / inch of circumference
M_o	unit applied line moment	in-lb / inch of circumference
M_r	unit radial bending	in-lb / inch of circumference
M_t	unit tangential bending	in-lb / inch of radius

row 120

row 130

CANTILEVER PLATE COMPARISON

q	**2371**	psi
L	1.96	in
M_pl	4554	lb-in
t_pl	1.00	in
S_pl	0.16667	in^3
f_b	27.32	ksi

row 140

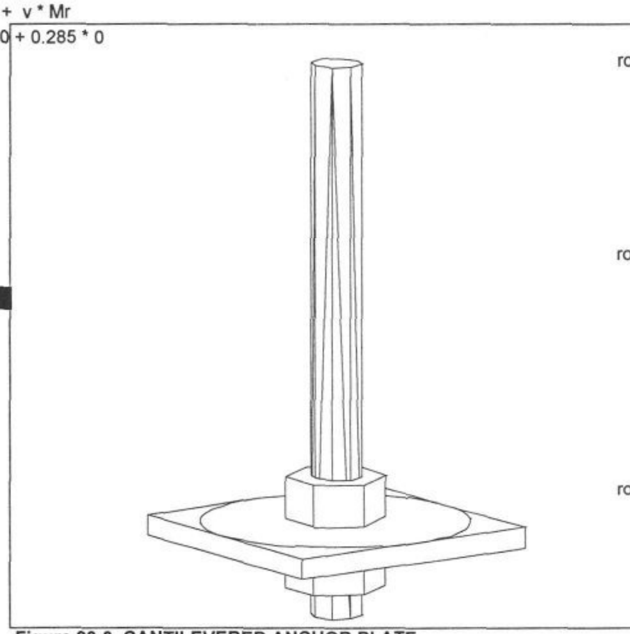


Figure 28-3 CANTILEVERED ANCHOR PLATE

row 150

ROARK FLAT PLATES
EXHAUST STACK

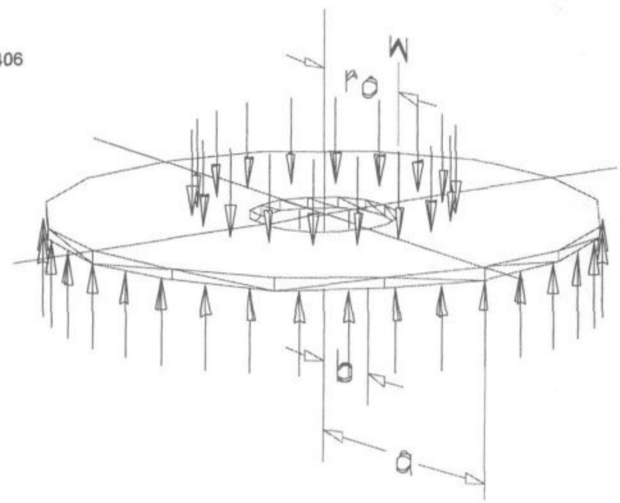
A B C D E F G H I J K L M N

FLAT CIRCULAR PLATES / CONSTANT THICKNESS -- Continued

Roark Table 24, Case 1a: Outer edge simply supported, inner edge free ... page 335

y_b'	0.1406		
y_b	0.00	in	-4,267 * 2.40^3 / 2,630,314 * 0.1406 (lb/in, in^3, / lb-in)
theta_b'	0.22		
theta_b	-0.001		
Mrb'	0.00		
Mrb	0.00		
Qb'	0.00		
Qb	0.00	lb/in	
y'	0.00		
y"	0.00		
y"'	0.00		
y""	0.00		
y	0.00		
theta'	0.00		
theta"	0.00		
theta"'	0.00		
theta""	0.00		
theta	-0.001		
Mr'	-266.80		
Mr"	0.00		
Mr"'	0.00		
Mr""	0.00		
Mr	-266.80	lb-in	
Mt	-1576.45	lb-in	tangential moment / inch of circumference MOMENT
S provided	0.1666667	in^3/in	1.0000^3 /6
fb	-9459	lb/in^2 /in	stress in plate
	-9.5	ksi	
Q	=B164*b/r_-W*ro/r_*___*_R_RO_		
theta_a			
Qa	-2844.89	lb / inch of circumference	SHEAR

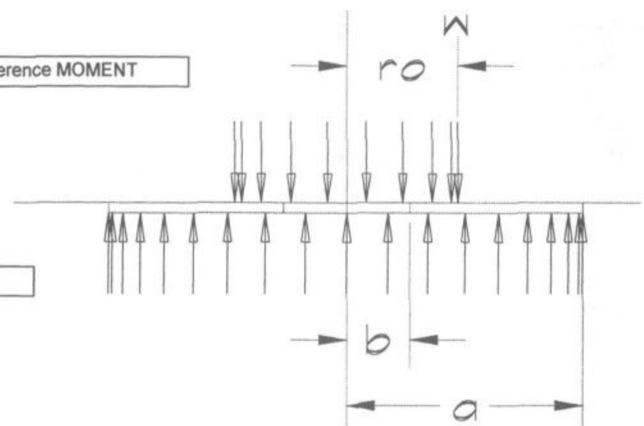
row 160



row 170

Figure 28-4 PLATE LOADING

row 180



row 190

Figure 28-5 PLATE LOADING

row 200

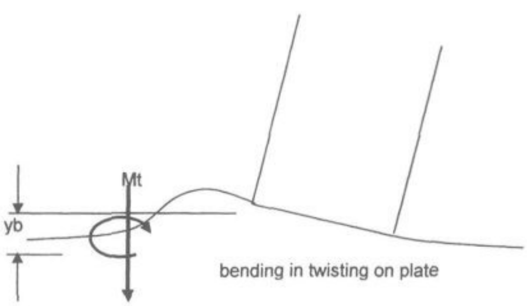


Figure 28-6 PLATE TWISTING

Figure 28-7 PLATE BENDING

row 210

row 220

A B C D E F G H I J K L M N

FLAT CIRCULAR PLATES / CONSTANT THICKNESS -- Continued

Values from above for Roark Table 24, Case 1a page 362

a	**2.4**	in	radius to outer edge
ro	**1.6**	in	radius to location of w
q	**2371**	lb/in^2	
t	**1**	in	thickness of plate
v	**0.285**	unit	poisson ratio
E	**29000000**	psi	Young's modulus of elasticity

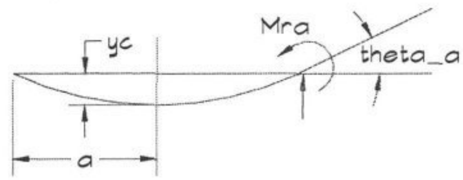


Figure 28-8 PLATE BENDING DIAGRAM

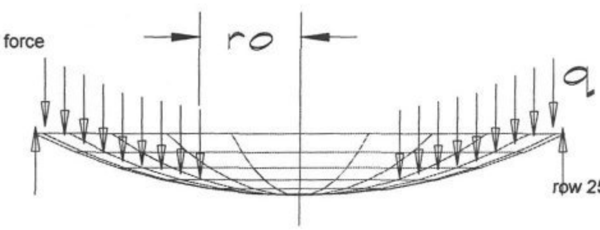
Roark, Table 24 Case 10a: Outer edge simply supported ... page 363

y_a	*0*	per Roark	supported edge
M_{ra}	0		simply supported edge
L_11	0.000		from above
L_17	0.045		from above
y_c	**-0.0005**	in	-q * a^4 /(2 * D) * (L_17 /(1 + v) - 2 * L_11) -2,371 * 2.400^4 /(2 * 2,630,314) * (0.04514 /(1 + 0.285) - 2 * 0.00044) deflection at center of plate

row 240

M_c	**616**	lb-in	q * a^2 * L_17 M at center of plate
S	0.1666667	in^3	
f_b	**3698**	psi	
q_a	0.0007	radians	q/(8*D*a*(1-v)) * (a^2-ro^2)^2
Qa	-1580.50		-q/(2*a)*(a^2-ro^2)
		L/9,374	

shear force



row 250

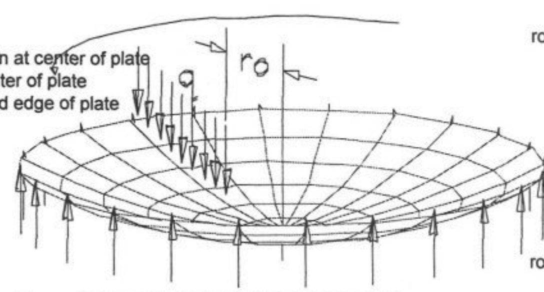
Figure 28-9 PLATE SUPPORT

Roark Table 24, Case 10b: Outer edge fixed supported ... page 363

ya	0	per Roark	supported edge
theta_a	0		fixed edge
L_11	0.000		from above
L_14	0.005		from above
L_17	0.045		from above
yc	0.000	in	-q*a^4/(2*D)*(L_14-2*L_11) deflection at center of plate
Mc	616.37	lb-in	q*a^2*L_17 M at center of plate
Mra	-526.832	lb-in	-q/(8*a^2)*(a^2-ro^2)^2 M at fixed edge of plate
		L/75,994	

row 260

S_plate	0.167	in^3	b*t^3/6
M	**616**	lb-in	
fb	*4*	*k/in^2*	



row 270

Figure 28-10 VIEW OF PLATE DEFLECTION

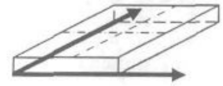
row 280

row 290

FOUNDATION LOADING INTRODUCTION
EXHAUST STACK

Christy
29
15:32
12/20/05

Not included on the CD-ROM

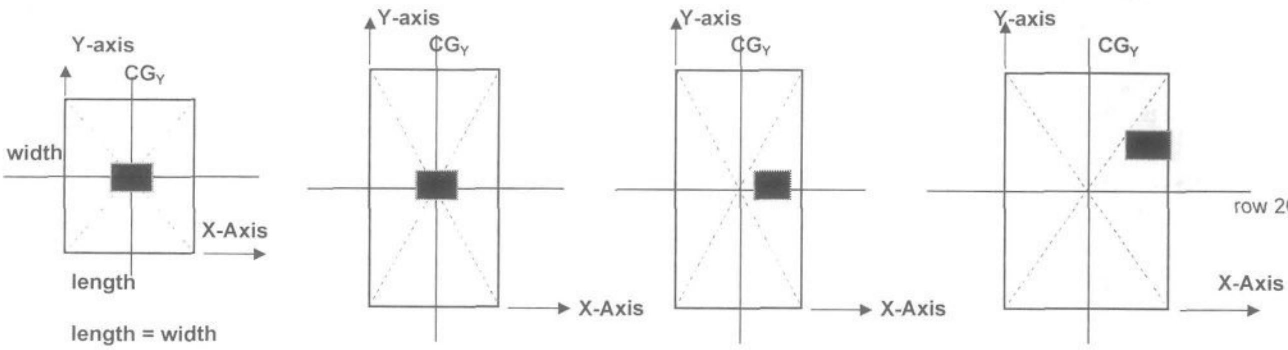


ENGINEERING with the SPREADSHEET

29 Foundation Loading Introduction.xls

A B C D E F G H I J K L M N

FOOTING CONFIGURATIONS



row 20

Concentrically Loaded Symmetric Footing — Concentrically Loaded Doubly Symmetric Footing — Eccentrically Loaded In YY Overturning — Eccentrically Loaded In X and Y Overturning

Figure 29-1 Loading configurations of eccentrically loaded rectangular footings. row 30

So long as all edges are positively loaded, any of these configurations can be calculated with the trapezoidal soil loading profile.

When an edge is unloaded X or Y overturning (but not both together) can be calculated with the triangular soil loading profile. Where a footing is eccentrically loaded in both X and Y overturning, loading can be determined using iterative calculations or the *Rotating Footing* template.

Theory Versus Reality

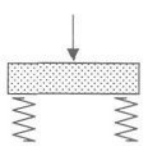
Concrete footings are designed as rigid elements which is conservative. Concrete is flexible and deflects into the soil. The interior of the footing loads the soil more than the edges do. row 40

A key element in soil loading is the soil modulus which is measured in lb /in^2 /in.
This value is usually given as lb /in^3.

Good soil usually has a modulus of 200 lb/in^3 or better.
I've built floating foundations on soil having a modulus of 20 lb/in^3.

Good fill will have a modulus of 400 to 500 lb/in3 but in conditions where soil modulus is poor, good fill results are not possible. Either a floating foundation or some type of piling is required. row 50

P	**10**	k
modulus	**20**	lb/in^3
Area	**4**	ft^2
d_{20}	**0.868**	in



10 k * 1000 lb/k /(4 ft * 144 ft/in^2) /20 lb/in^3

P	**10**	k
modulus	**200**	lb/in^3
Area	**4**	ft^2
d_{200}	**0.087**	in

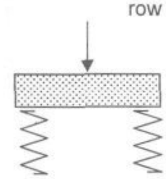


Figure 29-2 Deflections as governed by soil modulus.

row 60

Eccentrically loaded footings and floating foundations on poor soil risk significant differential deflections. Concrete flexibility and soil modulus should be considered together when differential deflections are calculated.

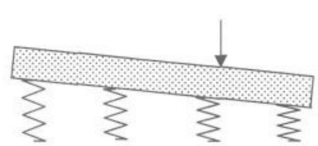


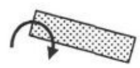
Figure 29-3 Differential deflections due to an eccentric loads.

row 70

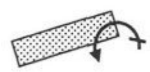
FOOTING CONFIGURATIONS -- Continued

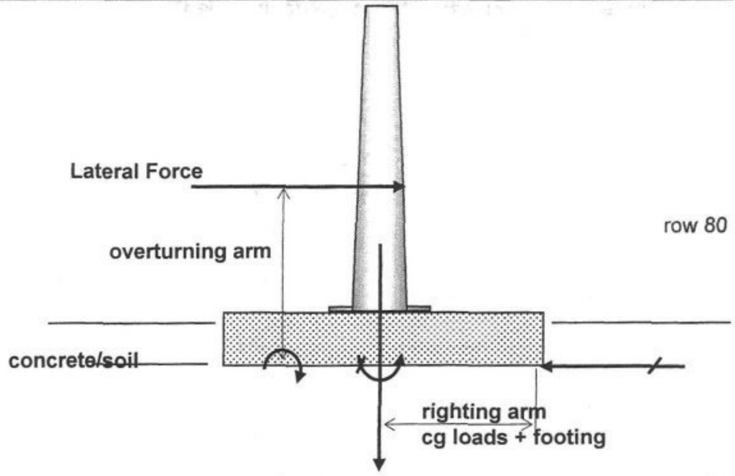
All forces are calculated at the concrete/soil interface -- not the top of the footing.

M_{OT} Lateral Force * overturning arm



M_{RT} righting arm * (loads + footing)





row 80

Figure 29-4 Applied forces and reactions.

row 90

No matter where a moment is placed along a line, the effect is the same. All of the moment symbols could be shown in the middle of the concrete/soil interface but then, you wouldn't be able to read the diagram.

→ acting force
←/– reaction

Generally, we try to design footings as concentrically loaded. Some footings must be eccentrically loaded when there is not enough room to locate the footing directly under the load.

Eccentrically loaded footings under expected dead and live loads should have all edges positively loaded. Eccentricity should conform to:

e < length/6

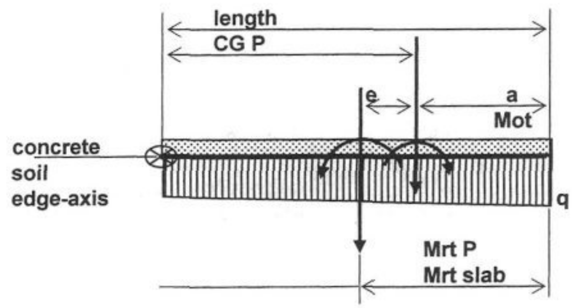


Figure 29-5 TRAPAZOIDAL FOOTING PROFILE

Footings subjected to lateral, overturning loads due to seismic, wind, or other impact loading may unload one edge. Soil does not work in tension. This results in a triangular soil loading profile.

row 110

If the footing demonstrates triangular loading in both directions, calculate the soil pressure with the *Rotating Footing* template.

The footing calculated here is a simple, doubly symmetric shape. Length and width can be different with the center of gravity of the footing in the exact, geographic middle.

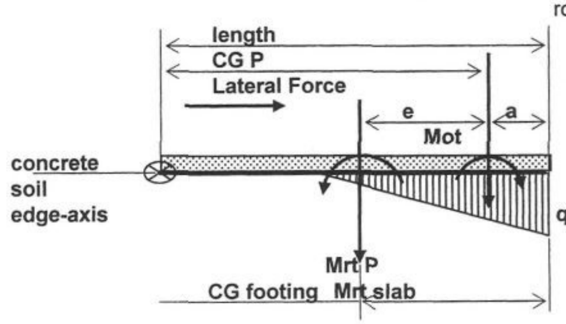
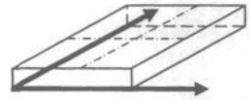


Figure 29-6 TRIANGULAR FOOTING PROFILE

⊗ X or Y axis normal to the page (in and out of the page)

row 130

FOUNDATION LOADING
EXHAUST STACK



A B C D E F G H I J K L M N

TRAPEZOIDAL SOIL LOADING, ALL EDGES LOADED 16.00' x 16.00' x 2.00'

The trapezoidal loading calculations are not included in the stack calculation set.

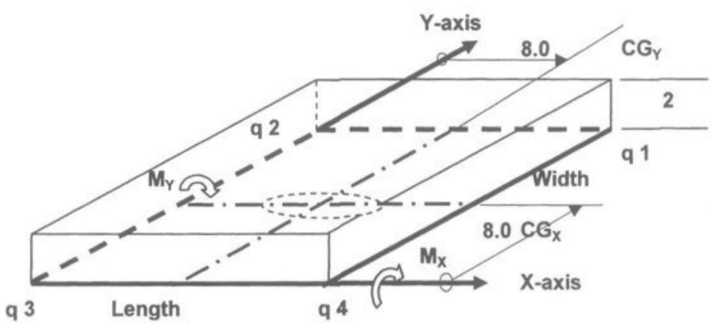


Figure 30-1 FOOTING VIEW

M_x	moment about the x-axis or an axis parallel to the x-axis, k-ft
Mot_x	overturning moment about the x-axis, k-ft
Mrt_x	righting moment about the x-axis from loads working in the opposite direction of Mot_x, k-ft
CG_x	center of gravity from the x-axis, ft. This is a distance from the x-axis, not a vector.
e_x	eccentricity of all loads including dead and live loads, the slab, and moment due to seismic or wind forces geographical center of gravity CG_X, ft
I_{XX}	moment if inertia about the x-axis or an axis parallel to the x-axis, ft^4
q_x	soil pressure along the loaded, top, edge, ksf

row 30

from x ↑	**16.00** ft	width of slab	from y →	**16.00** ft	length of slab
I_{XX} ↑	5461 ft^4	rotate about axis parallel to XX	I_{YY} →	5461 ft^4	
CG_X ftg ↑	8.0 ft	from the bottom edge	CG_Y ftg →	8.0 ft	from the left edge

Locate the Structure CG on the Slab

CG P_X ↑	**8.0** ft	from the bottom edge	CG P_Y →	**8.0** ft	from the left edge

h_slab	**2.00** ft	slab depth
Area	256 ft^2	
weight c	76.8 k	weight of concrete
	19.0 $yard^3$	volume of concrete
P_{DL}	**6.944** k	dead loads
P_{LL}	**0.000** k	live loads
$P_{DL\,LL}$	**6.944** k	sum of structure DL + LL
P sum	**83.744** k	sum of structure DL + LL + concrete footing

q at rest	1.309 ksf

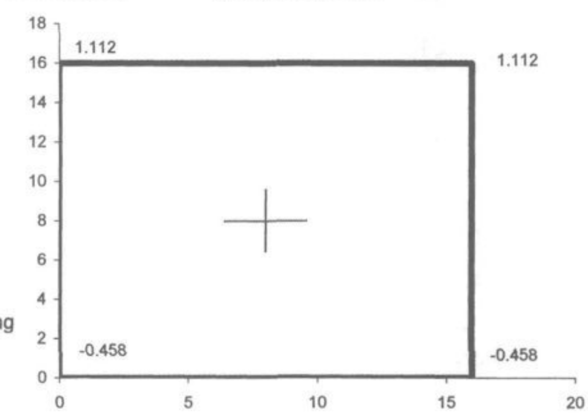
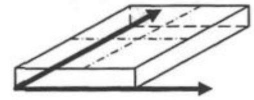


Figure 30-2 Footing loaded under entire footing bearing area in trapezoidal loading.

row 60

	ASD values			ASD values	
Mot_x ↑	**536.1** k-ft		Mot_Y →	**0.0** k-ft	
Mrt DL_X	55.6 k-ft		Mrt DL_Y	55.6 k-ft	
Mrt LL_X	0.0		Mrt LL_Y	0.0	
Mrt $slab_X$	614.4		Mrt $slab_Y$	614.4	
sum Mrt_X	**670.0**		sum Mrt_Y	**670.0**	

row 70



A B C D E F G H I J K L M N

TRAPEZOIDAL SOIL LOADING, ALL EDGES LOADED -- Continued 16.00' x 16.00' x 2.00'

a_X	1.60 ft	(Mrt_X - Mot_X) / p_sum	a_Y	8.00 ft	(Mrt_Y - Mot_Y) / p_sum
		(670.0 - 536.1) /83.744			(670.0 - 0.0) /83.744
cg_X ↑	8.00 ft	from loaded top edge	cg_Y →	8.00 ft	from loaded right edge
e_X	6.40 ft	$cg_X - a_X$	ey	0.00 ft	$cg_Y - a_Y$

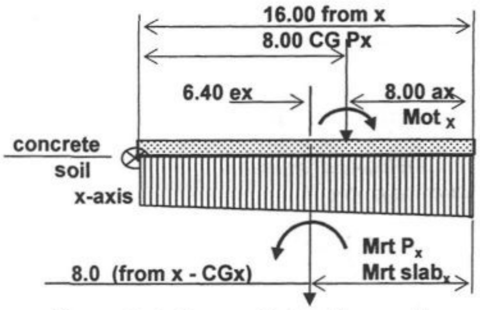


Figure 30-3 Trapezoidal footing profile rotating about the x-axis for Mot x.

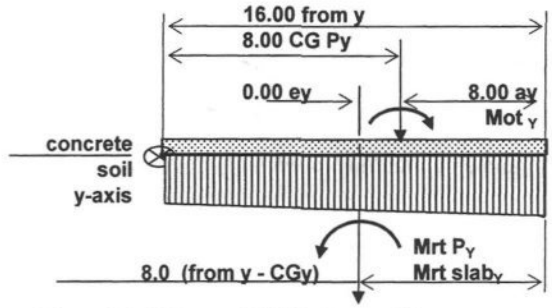


Figure 30-4 Trapezoidal footing profile rotating about the y-axis for Mot y.

row 80

row 90

Trapezoidal q in X and Y Directions

	P/A	± Pe_Xc_X / I_{XX} ↑	sum q	P/A	± Pe_Yc_Y / I_{YY} →	sum q
q 1 & 2	0.327	0.785	**1.112** ksf	0.327	0.000	**0.327** ksf
q 3 & 4	0.327	-0.785	-0.458 ksf !!!	0.327	0.000	**0.327** ksf .

row 100

Trapezoidal q at Each Corner

	P/A	± Pe_Xc_X / I_{XX} ↑	± Pe_Yc_Y / I_{YY} →	sum q
q 1	0.327	0.785	0.000	1.112 ksf
q 2	0.327	0.785	0.000	1.112 ksf
q 3	0.327	-0.785	0.000	-0.458 ksf
q 4	0.327	-0.785	0.000	-0.458 ksf

These flaged loadings indicate that triangular loading calculations apply

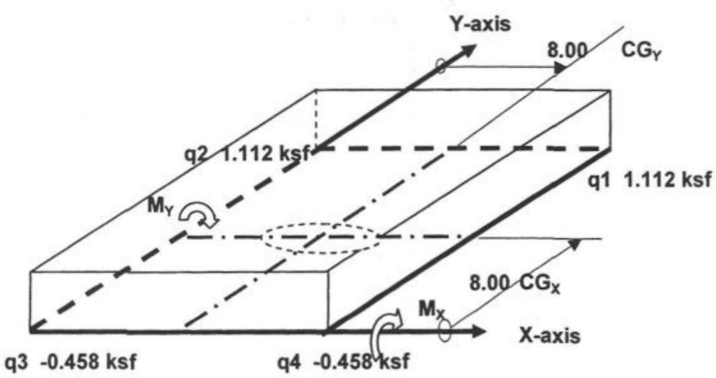


Figure 30-5 Trapezoidal bearing values.

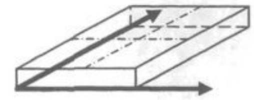
All values to calculate soil pressure are taken from the concrete/soil interface, not the top of the slab.

row 120

Anchor bolt values are calculated at the top of the slab.

row 130

FOUNDATION LOADING
EXHAUST STACK



A B C D E F G H I J K L M N

TRIANGULAR SOIL LOADING FOR ROTATION IN X OR Y ONLY 16.00' x 16.00' x 2.00'

Soil cannot work in tension under a footing. However, the footing can exert force on just part of its available bearing area.

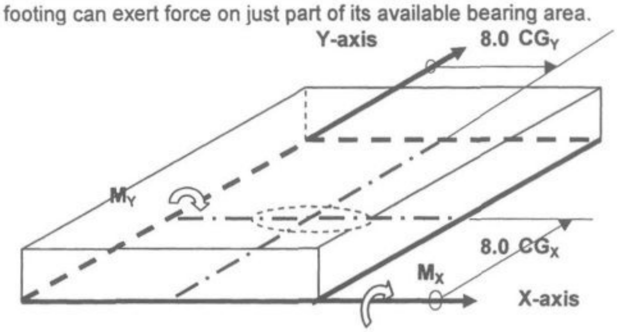


Figure 30-6 FOOTING VIEW

M_X	moment about the x-axis or an axis parallel to the x-axis, k-ft
Mot $_X$	overturning moment about the x-axis, k-ft
Mrt $_X$	righting moment about the x-axis from loads working in the opposite direction of Mot $_x$, k-ft
CG_X	center of gravity from the x-axis, ft
e_X	eccentricity of all loads including dead and live loads, the slab, and moment due to seismic or wind forces geographical center of gravity CG_X, ft
I_{XX}	moment if inertia about the x-axis or an axis parallel to the x-axis, ft^4
q $_x$	soil pressure along the loaded, top, edge, ksf
a $_X$	the 1/3 point of the triangular soil loading profile, ft

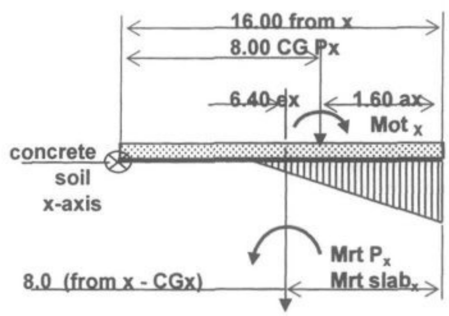


Figure 30-7 Triangular footing profile rotating about the x-axis.

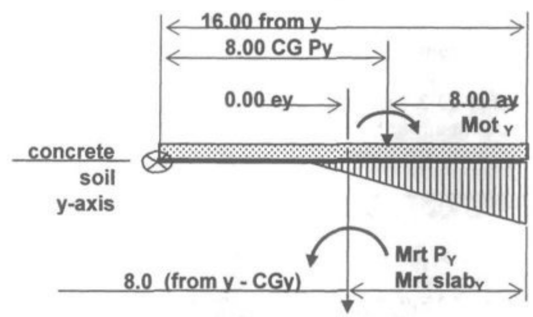
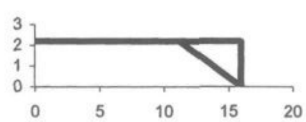


Figure 30-8 Triangular footing profile rotating about the y-axis.

row 150

row 160

from x ↑	**16.00**	ft	width along Y-axis	from y →	**16.00**	ft	length along X-axis	
CG $_X$ ↑	8.0	ft	geographical location	CG $_Y$ →	8.0	ft		
CG P_X ↑	**8.0**	ft	geographical location	CG P_Y →	**8.0**	ft		
P sum	**83.7**	k	sum of structure DL + LL + slab					row 170
Mot $_X$ ↑	**536.1**	k-ft	working wind or seismic	Mot $_Y$ →	**0**	k-ft	toward the right edge	
Mrt struct $_x$	55.6	k-ft	structure from the top edge	Mrt struct $_y$	55.6	k-ft	structure from the right edge	
Mrt slab $_x$	614.4	k-ft	slab from the top edge	Mrt slab $_y$	614.4	k-ft	slab from the right edge	
cg $_X$	8.0	ft	from loaded top edge	cg $_Y$	8.0	ft	from loaded right edge	
e $_X$	6.40	ft .		e $_Y$	0.00	ft .		
e's	1	logic	OK only one eccentricity					
a $_X$	1.60	ft		a $_Y$	8.00	ft		row 180



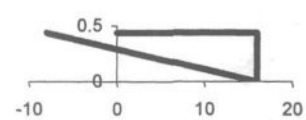


Figure 30-9 Triangular bearing profiles.

q $_x$ 1 & 2	**2.183**	ksf .	2*P sum / (3*edge_x*(edge_y/2-e_x))	q $_y$ 1 & 3	**0.436**	ksf .	2*P sum / (3*edge__y*(edge__x/2-e_y))

row 190

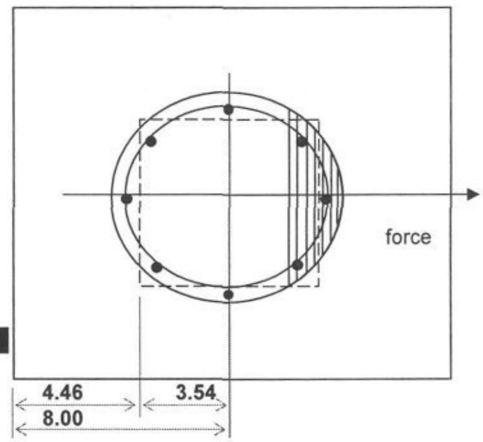
FOUNDATION DESIGN
EXHAUST STACK

A B C D E F G H I J K L M N

CONCRETE DESIGN IN UPLIFT

For Bolt Circle

cg	**8.00**	ft	longest cg to be considered
radius	**2.00**	ft	radius of tank pads or bolts from CL tank
box	3.54	ft	(PI()*radius^2)^0.5 equivalent side of square
arm	4.46	ft	
slab_h	**2.00**	ft	depth of slab
q_ult	0.42	ksf_ult	1.4 * slab_h * 0.15 k/ft^3
Pu	1.9	k_ult	
Mu	**4.2**	k-ft_ult	top reinforcing in tension



row 20

Figure 31-1 CIRCULAR LOADING PLAN

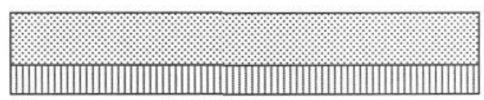
row 30

LRFD FACTORING '97 UBC

DL	1.309	ksf
wind+DL	2.183	ksf
wind	0.874	ksf

1612.2.1 Basic load combinations with exception 2 -- multiply loads with 1.1 for loads including seismic forces

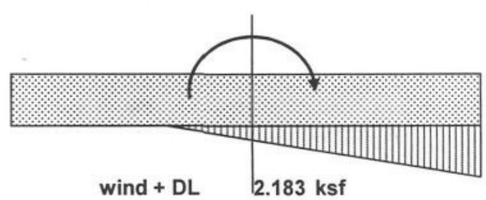
D	**1.309**		dead load -- max DL righting moment
L	**0**		live load or earth pressure
L_r	**0**		roof live load
S	**0**		snow
W	**0.874**		wind
E	**0**		seismic -- when derived from the UBC, use E/1.4
T	**0**		differential settlement
H	**0**		earth pressure
F	**0**		fluid pressure, load factor = 1.4
f 1	**1.0**		1.0 floors in public assembly, LL >100 psf, garage 0.5 of other live loads
f 2	**0.2**		0.7 roofs that can't shed snow, 0.2 other
E_	**1.1**	multiplier	use 1.1 for concrete and masonry subjected to seismic forces



DL 1.309 ksf
LL 0.000 ksf

Figure 31-2 At-rest DL and LL loads.

row 40



row 50

Figure 31-3 Overturning soil loading profile.

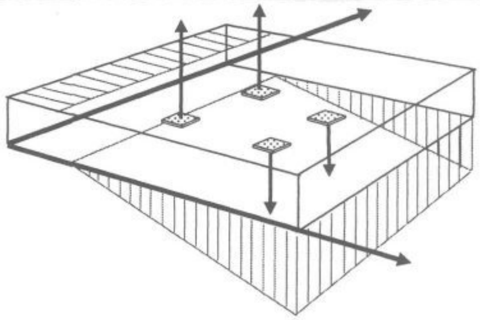
12-1	2.016		1.1 * 1.4 D
12-2	1.728		1.1 * (1.2D + 1.6*L +0.5* (L or S))
12-3	2.497		1.1 * (1.2D + 1.6(Lr or S) + (f_1 L or 0.8W))
12-4	2.978		1.1 * (1.2D + 1.3W +f_1 L + 0.5(Lr or S))
12-5a	1.728		1.1 * (1.2D + 1.0E + (f_1 LL_ + f_2 S))
12-6a	2.546		1.1 * (0.9D + 1.0E or 1.3W)
12-6b	2.546		1.1 * (0.9D - 1.0E or 1.3W)
max	2.978	ksf ult	
1909.2			
9-1	1.833		1.4D + 1.7L
9-2a	2.489		0.75 (1.4D + 1.7L + 1.7W)
9-2b	1.512		1.1 * 0.75 (1.4D + 1.7L + 1.7E)
9-3a	2.314		0.9D + 1.3W
9-3b	1.440		1.1 * (0.9D + 1.3 E)
9-4a	1.833		1.4D + 1.7L + 1.7H
9-4b	1.178		0.9D + 0L + 1.7H
9-5	1.374		0.75 (1.4D + 1.4T + 1.7L)
9-6	1.833		1.4 (D + T)
max	2.489	ksf ult	
ratio	1.364		wind + DL ultimate / wind + LL

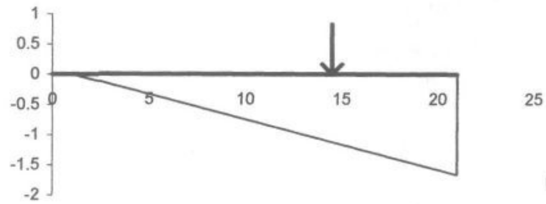
row 60

row 70

A B C D E F G H I J K L M N

CONCRETE DESIGN IN BEARING

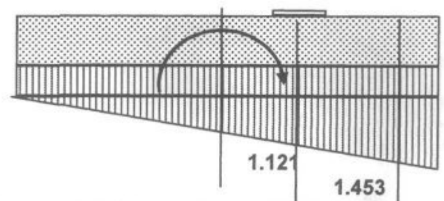




row 80

Figure 31-5 SOIL PRESSURE PROFILE

Figure 31-4 SOIL PRESSURE VIEW



row 90

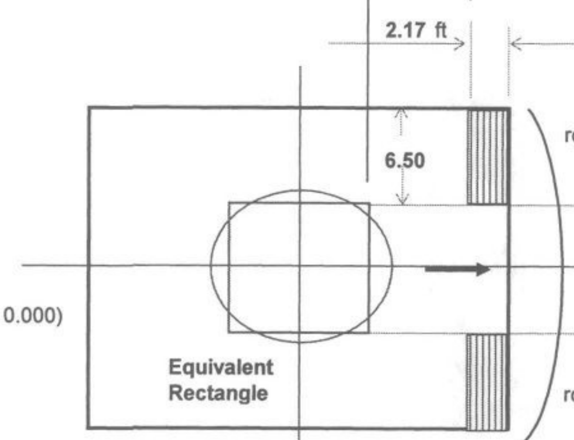
Figure 31-6 SOIL PRESSURE DIAGRAM

q loaded	**1.661**	ksf	soil pressure loading slab + DL + LL
q unload	**0.000**	ksf	
3a	**19.98**	ft	3 * a_x or a_y or length/width of footing
L	**21**	ft	length of footing in direction of 3a
W	**17**	ft	width of footing perpindicular to direction of vessel movement
h	**2.5**	ft	depth of footing
d	**2.17**	ft	
ratio	**0.893**	unitless	ratio of LRFD to ASD loads
ratio use	**1**	unitless	use this ratio of LRFD to ASD loads

Moment One

Determine cantilever moment from face of equivalent square.
Use and averaged soil pressure agains an approximated beam of width = d.

Cant 1	**6.50**	ft	cantilevered slab approximated to face of equivalent square
q triangle	1.453	ksf	(1 - 2.50 /MIN(21.00, 19.98)) * (1.661 - 0.000)
q rect	0.000	ksf	
q avg	1.453	ksf	
M	30.7	k-ft	
Mu	**30.7**	**k-ft ult**	



row 100

row 110

Figure 31-7 LOADING PLAN

Moment 2

CG down	**6.5**	ft	baseplate(s) bearing down to loaded edge
	0		
M	**-2.7**		full triangle
q triangle	1.121	ksf	(1 - 6.50 /MIN(21.00, 19.98)) * (1.661 - 0.000)
q rect	0.00	ksf	
q	1.121	ksf	for reference
M 2	15.8	k-ft	6.50 * 2/3 * 1.121 * 6.50 /2
M 3	0	k-ft	0.000 * 6.50^2 /2
M sum	15.8	k-ft	
Mu	**15.8**	**k-ft ult**	

row 120

Figure 31-8 LOADING PLAN

row 130

The Concrete Beam Template

The concrete beam template can be used for singly and doubly reinforced rectangular, spandrel, and T beams. It is a documented and range named template suitable for study or explaining your design to the Building Official.

American Concrete Institute
http://www.aci-int.org/general/home.asp

Inputs
Dimensions and reinforcing

Summary Output
Mu provided
Moments of inertia

Gross Moment of Inertia
Including **$+A_s$** and **$-A'_s$**
$w\ x\ x/2 = n\ A'_s\ (x - d') + n\ A_s\ (d' - x)$

row 20

ρ minimum
Minimum density of reinforcing
$3\ \sqrt{f'_C}\ /f_y\ b_w\ d$ 02 ACI 10.5.1 (10-3)
$200\ b_w\ d\ /\ f_y$ ACI 21.3.2 seismic

Effective Moment of Inertia
Using the cracked section

row 30

Rectangular/ T-beam Logic

Creep versus Time

Temperature Reinforcing

β1 Reduction Factor
reduce the .85 factor by .05 for each 1000 psi over 4000 psi

Balanced Strain
$\varepsilon'_c\ /\ (\ \varepsilon'_c + \varepsilon_t/E_s\ )\ d$

Whitney's Stress Block
$\beta_1 * x_{balance} = a$ max stress block

Tension Reinforcing Strain
$\varepsilon_t = f_y\ /E_s$

row 40

row 50

Solution for $x_{balance}$ Strain
Using the quadratic equation

Calculation of M_n and M_u
$M_n = a\ b_w\ arm = T_s\ arm$
$M_u = 0.9\ M_n$

row 60

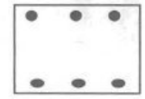
Verifying Graphs

Figure 32-1 TEMPLATE LAYOUT

row 70

REINFORCED CONCRETE BEAM
EXHAUST STACK

33



Christy
18:10
12/20/05

ENGINEERING with the SPREADSHEET

33 Concrete Beam.xls

A B C D E F G H I J K L M N

CONCRETE BEAM DESIGN — I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4

f_y	**60**	ksi	yield strength of reinforcing
f'_c	**3**	ksi	compressive strength of concrete
d'	**2.5**	in	depth of compression reinforcing
b_w	**13**	in	width
d	**20.5**	in	depth of tension reinforcing
depth_OA	**27**	in	overall depth

	Bar Qty	Bar Size#	A_s
A'_s	**0.00**	**6**	0.00 in^2
A_s	**1.00**	**6**	0.44 in^2

M working	**21.9**	k-ft	required service level moment
M_u req'd	**30.7**	k-ft ult	required ultimate/factored moment

M_U prov 39.80 k-ft ultimate provided

OK Beam stressed to 77 % **NOTE: 77% ≈ 75%**

!!! As min 0.89 > As provided 0.44 **see ρ_{min} below**

OK x balance 7.62 ≥ 0.937 required

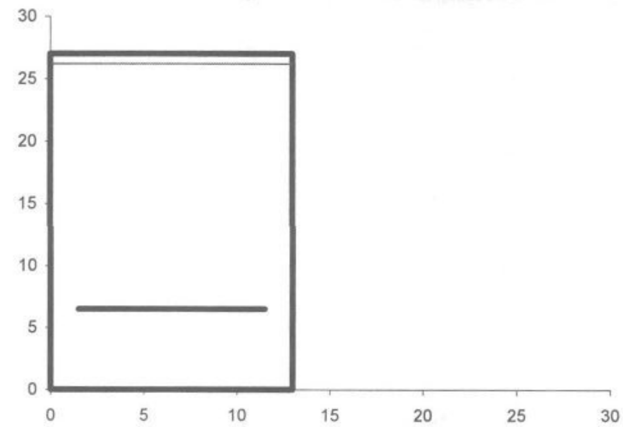


Figure 33-1 Beam cross-section with Whitney's stress block and reinforcing. row 30

Bar Size #		in American nomenclature, bar size is given as a number which equates to 8 th's of an inch hence, a #6 bar is 6/8 inch = 3/4"
f_y		ultimate tensile strength of reinforcing, k/in^2
f'_c		ultimate compression strength of concrete, k/in^2

Length	**39**	ft	length of joist
t	**4.5**	in	thickness of slab
c	**78**	in	spacing of joists
flange	**0**	logic	0 = no flanges, 1 = spandrel, 2 = T beam

American Concrete Institute row 40
http://www.aci-int.org/general/home.asp

I_g	21500	in^4	
$I_{cracked}$	1365	in^4	
I_e	21500	in^4	
ε_t	0.00507	unitless	allowable tension reinforcing strain
			0.00400 minimum strain allowed

ρ_{min} -- Minimum Reinforcement in Flexural Members

A_s min $_1$	0.73 in^2	$3\ \sqrt{f'_C}\ /f_y\ b_w\ d$ 02 ACI 10.5.1 (10-3) 3 * √ 3 *1000 * 13.0 * 20.5 /60 /1000
A_s min $_2$	0.89 in^2	200 * w * d /f_y /1000 02 ACI 10.5.1 200 * 13.0 * 20.5 /60 /1000
A_s logic	0 logic	MAX(0.89, 0.73) ≤ 0.44

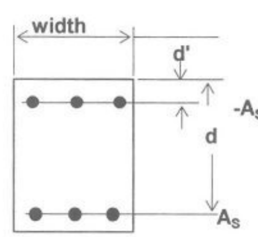


Figure 33-2 Beam cross-section.

row 50

When the area of tension reinforcing steel is less than **$+A_s$** minimum, the amount of reinforcing provided must be increased by 1/3 beyond that needed for tensile reinforcement. 02 ACI 10.5.3

When the beam is stressed to 75% and **$+A_s$ = 1.33 x A_s** provided, the minimum requirements of reinforcement have been met.

row 60

$-A_s$, A'_s	negative reinforcing - usually the top steel, in^2
$+A_s$	positive reinforcing - usually the bottom steel, in^2

For Seismic Resistance

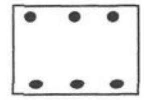
A_s min	0.89 in^2	200 * b_w * d / f_y ACI 21.3.2 200 * 13 * 20.5 /60 /1000

row 70

CONSULTING COMPANY

REINFORCED CONCRETE BEAM
EXHAUST STACK

33



Christy
18:10
12/20/05

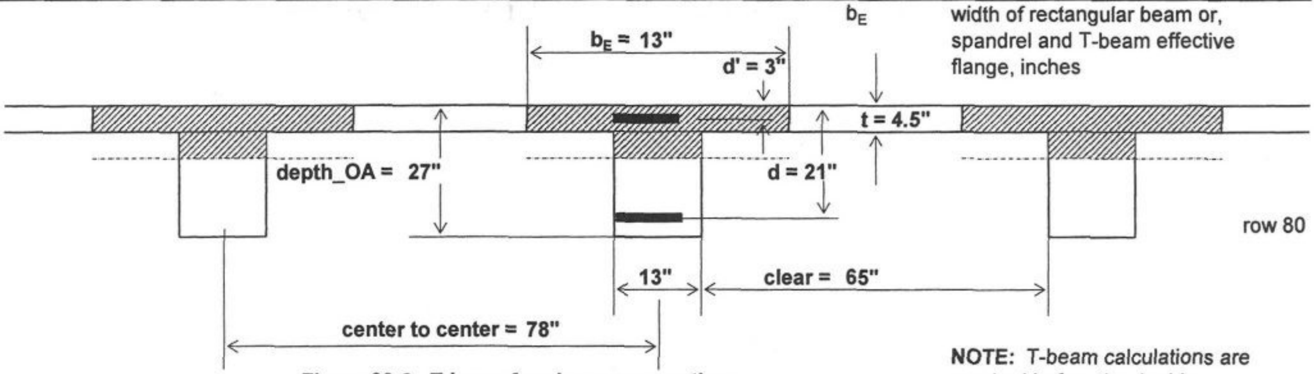
ENGINEERING with the SPREADSHEET

33 Concrete Beam.xls

A B C D E F G H I J K L M N

CONCRETE BEAM DESIGN -- Continued I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4

b_E width of rectangular beam or, spandrel and T-beam effective flange, inches



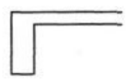
row 80

Figure 33-3 T-beam framing cross section.

NOTE: *T-beam calculations are required before the doubly reinforced calculations can be done.*

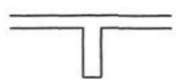
Spandrel beam ACI 8.10.3 row 90

b_E	39	in	39' * 12 in/ft /12
b_E	40	in	4.5" * 6 + 13" beam width
b_E	45.5	in	(78" - 13" beam width) /2 + 13"
b_E	39	in	spandrel



T-beam 02 ACI 8.10.2

b_E	117	in	39' * 12 in/ft /4
b_E	85	in	4.5" * 16 + 13" beam width
b_E	78	in	78" c-c beam spacing
b_E	78	in	maximum width of flange
b_E	78	in	



row 100

Type of beam and overhang

slab trib	b_E	logic	b_E	overhang OH
beam	13	1	13	0
spandrel	39	0	0	0
T-beam	78	0	0	0
			13	0

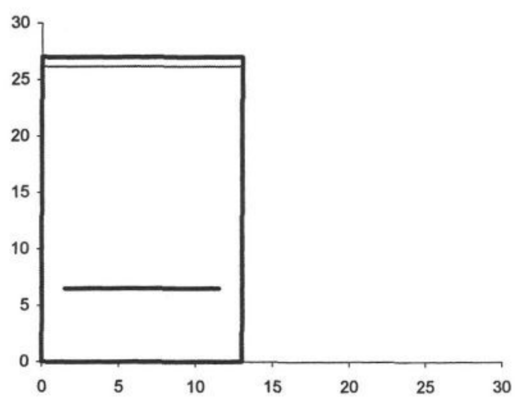


Figure 33-4 Beam cross-section.

vLookUp Table

Bar	Area
10M	0.12
15M	0.27
20M	0.49
25M	0.76
30M	1.1
35M	1.49
45M	2.47
55M	3.68
0	0
3	0.11
4	0.2
5	0.31
6	0.44
7	0.6
8	0.79
9	1
10	1.27
11	1.56
14	2.25
18	4

	Bar	Area
top	6	0.00

	Bar	Area
bottom	6	0.44

row 130

STRESS-STRAIN RELATIONSHIPS

I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4

β_1 0.85 unitless — reduce the .85 factor by .05 for each 1000 psi over 4000 psi
IF(3 ksi > 4, 0.85 - (3 ksi - 4) * 0.05, 0.85)

β_1 0.85 — but not less than 0.65
IF(0.85 < 0.65, 0.65, B210)

ε'_s limit 0.00207 unitless — f_y / E_s
60 / 29000 compression strain for reinforcing full engagement

ε_t **0.00507** unitless — allowable tension reinforcing strain
0.00400 minimum strain allowed

ε_t 0.00207 unitless — 60 fy / 29,000 Es calculated for reference only

B 1, β_1 — reduction factor for higher strengths of concrete, unitless. ACI 10.2.7
a space is included between the B and the 1 so that the spreadsheet does not read this range name as a cell address.

E_S — steel modulus of elasticity, 29000 ksi

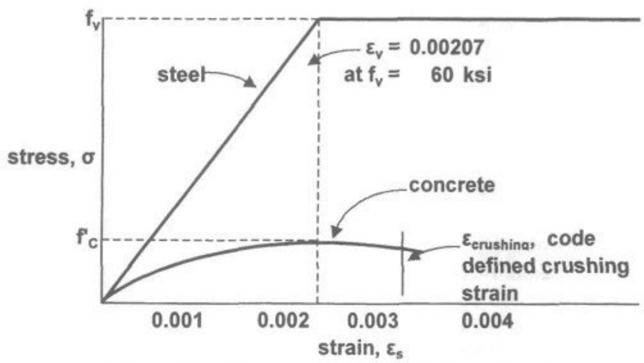


Figure 33-5 Stress and strain relationships for concrete and steel.

Note: that ε_t is the lower limit for tension reinforcing strain where the minimum = **0.0040**. This is conservative and may be increased to **0.005** where greater ductility is required as for tension controlled members. See **02 ACI 10.3.3, 10.3.4** and, **10.3.5**. commentary for a comprehensive explanation of this new approach in the code. Older codes used **0.75 ρ_b**.

To follow some textbook examples, you will have to set ε_t to **0.00207** or greater.

$x_{balance}$	7.62 in	0.003 /(0.003 + 0.00507) * 20.50"
a_{max}	6.48 in	0.85 * 7.62 in
ε'_s	0.00807 unitless	20.50" /7.62" * 0.003
ε'_s min	0.00207 unitless	MIN(0.00807, 0.00207)

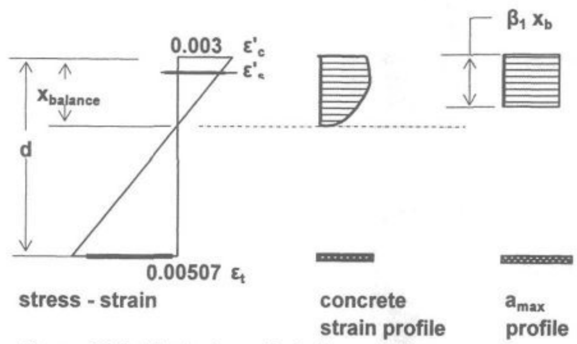


Figure 33-6 The balanced strain condition.

Stated another, traditional way;
the basic relationship to determine **x_balance * d** is:

ε'_c	87 unitless	0.003 * 29,000 ksi
ε_t/E_s	147.03 ksi	29000 /0.00507

row 170

$$x\ bal * d \quad \frac{\varepsilon'_c}{\varepsilon'_c + \varepsilon_t/E_s} = \frac{0.003}{0.003 + f_y/29{,}000} = \frac{87}{87+147} = 0.372 \ * d \text{ inches} = 7.62 \text{ in}$$

The Limit for Tension Reinforcing

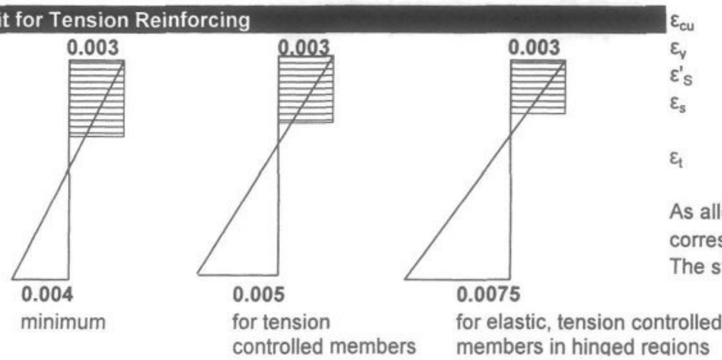


Figure 33-7 Tensile strain versus depth of compression block.

ε_{cu} — concrete crushing strain, 0.003, unitless
ε_y — strain at first yeild, unitless
ε'_S — strain in compression reinforcing, unitless
ε_s — strain in tension reinforcing, unitless

ε_t — allowable tension reinforcing strain, unitless

As allowable tension reinforcing strain ε_t increases, the corresponding Whitney's stress block decreases.
The stress block is a function of $\beta_1 * x_{balance} = a$.

row 190

REINFORCED CONCRETE BEAM
EXHAUST STACK

A B C D E F G H I J K L M N

DEPTH of COMPRESSION BLOCK I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4

For tension and compression forces -- solve for **x**.

Setup relationships to be solved with the quadratic equation: $[-b \pm (b^2 - 4\,a\,c)^{1/2}] / [2\,a] = 0$

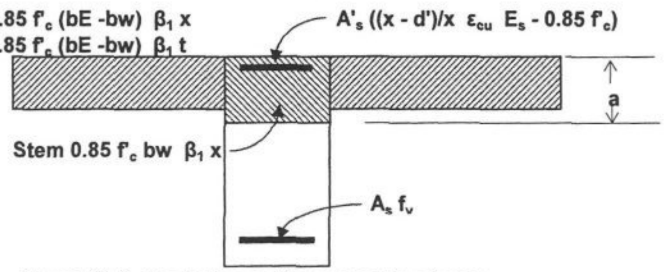


Figure 33-8 The balance of compression forces *against the tension force* $A_s\,f_v$.

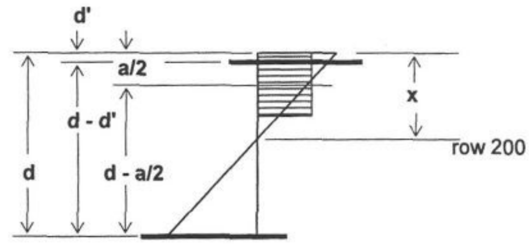


Figure 33-9 Calculating Whitney's stress block.

Calcualte x $_{balance}$ strain

Tension	Stem	Flange	Compression Reinforcing			
$A_s f_v =$	$0.85 f'_c\, bw\, \beta_1 x$	$0.85 f'_c (bE - bw)\, \beta_1 (x \text{ or } t)$	$+A'_s ((x - d')/x\, \varepsilon_{cu}\, E_s - 0.85 f'_c)$			row 210
$A_s f_v =$	$0.85 f'_c\, bw\, \beta_1 x$	$0.85 f'_c (bE - bw)\, \beta_1 (x \text{ or } t)$	$+A'_s (x - d')/x\, \varepsilon_{cu} E_s$	$-A'_s\, 0.85 f'_c$		
$A_s f_v$	$-0.85 f'_c\, bw\, \beta_1 x$	$-0.85 f'_c (bE - bw)\, \beta_1 (x \text{ or } t)$	$-A'_s\, 0.85 f'_c$	$= A'_s (x - d')/x\, \varepsilon_{cu}\, E_s$		
$A_s f_v$	$-0.85 f'_c\, bw\, \beta_1 x$	$-0.85 f'_c (bE - bw)\, \beta_1 (x \text{ or } t)$	$-A'_s\, 0.85 f'_c$	$= A'_s\, \varepsilon_{cu}\, E_s$	$-A'_s\, d'/x\, \varepsilon_{cu}\, E_s$	
$A_s f_v$	$-0.85 f'_c\, bw\, \beta_1 x$	$-0.85 f'_c (bE - bw)\, \beta_1 (x \text{ or } t)$	$-A'_s\, 0.85 f'_c$	$-A'_s\, \varepsilon_{cu}\, E_s$	$= -A'_s\, d'/x\, \varepsilon_{cu}\, E_s$	
$A_s f_v x^2$	$-0.85 f'_c\, bw\, \beta_1 x^2$	$-0.85 f'_c (bE - bw)\, \beta_1 (x \text{ or } t)\, x$	$-A'_s\, 0.85 f'_c\, x$	$-A'_s\, \varepsilon_{cu}\, E_s\, x$	$= -A'_s\, d'\, \varepsilon_{cu}\, E_s$	row 220

Where the compression block a is less than flange depth t

a			b				c	
$-0.85 f'_c\, bw\, \beta_1 x^2$	$-0.85 f'_c (bE - bw)\, \beta_1 x^2$		As fy x	$-A'_s\, 0.85 f'_c\, x$	$-A'_s\, \varepsilon_{cu}\, E_s\, x$		$+A'_s\, d'\, \varepsilon_{cu}\, E_s$	= 0
a x²			**b x**				**c**	
-28.178	0	**-28.178 k/in**	0.0	0.0	26.4	**26.4 k**	**0 k-in**	= 0

x	0.94 in	$[-b \pm (b^2 - 4\; a\; c)^{1/2}] / [2\; a] = 0$ [-26.4 + (26.4² - 4 * -28.178 * -0)^0.5] /[2 * -28.178]
	1 logic	OK x balance 7.62 ≥ 0.94
a	**0.796** in	0.94 * 0.85
	0 logic	0.796 < 4.5 flange

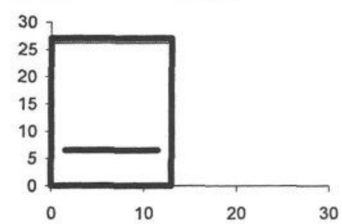


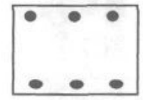
Figure 33-10 Beam cross-section.

Where the compression block a is greater than flange depth t

a	b					c	
$-0.85 f'_c\, bw\, \beta_1 x^2$	As fy x	$-A'_s\, 0.85 f'_c\, x - A'_s\, \varepsilon_{cu}\, E_s\, x - 0.85\, fc\, (bE - bw)\, t\, x$				$+A'_s\, d'\, \varepsilon_{cu}\, E_s$	= 0
a x²	**b x**					**c**	
-28.178	0.0	0.0	26.4	0.000	**26.4**	**0**	= 0

x	0.94 in	$[-b \pm (b^2 - 4\; a\; c)^{1/2}] / [2\; a] = 0$ [-26.4 + (26.4² - 4 * -28.178 * -0)^0.5] /[2 * -28.178]
	1 logic	OK x balance 7.62 ≥ 0.94
a	**0.796**	
	0.796	

row 250



DEPTH of COMPRESSION BLOCK -- Continued — I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4

x	**0.94**	in	IF(0, 0.94, 0.94)
a	0.796	in	0.94 * 0.85

x — distance of the neutral axis from extreme compression fiber, in

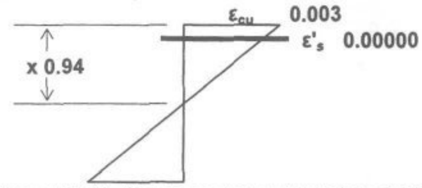
a — Whitney's compression block

Direct calculation of compression reinforcing stress

ε'_s	0.00000	unitless	MAX((0.94 - 2.5) /0.94 * 0.003, 0)
ε_y	0.00207	unitless	60 /29000
f'_y	0	ksi	MIN(0.00000 /0.00207 * 60, 60)

ε'_s — compression strain

ε_y — compression strain limit



row 200

Figure 33-11 Compression reinforcing strain.

Calculate compression forces and moments

C_s	0.0	k	(0 - 0.85 * 3) * 0.00
C_c stem	26.4	k	0.85 * 3 * 13 * 0.796
C_c flange	0.0	k	0.85 * 3 * MIN(0.796, 4.5) * (13 - 13)
Mn C_s	0	k-in	(20.5 - 2.5) * 0.0
Mn stem	531	k-in	26.4 * (20.5 - 0.796 /2)
Mn flange	0	k-in	0.0 * (20.5 - MIN(4.5, 0.796) /2)
M_n	531	k-in	0 + 531 + 0
M_n	44	k-ft	531 / 12 in/ft
M_u	**40**	k-ft ult	0.9 * 531
	77	%	M_u required / M_u
	1	logic	40 provided > 31 required
	1		OK x balance 7.62 ≥ 0.937 required

C_s — force in compression reinforcing, k

C_c — force in compressed concrete, k

M_n — ultimate moment, k-ft row 210

M_u — Mn a reduced by 0.9, k-ft ultimate

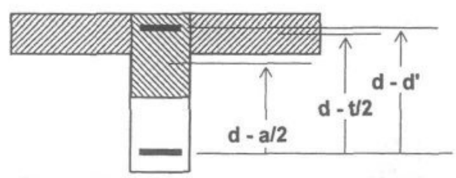
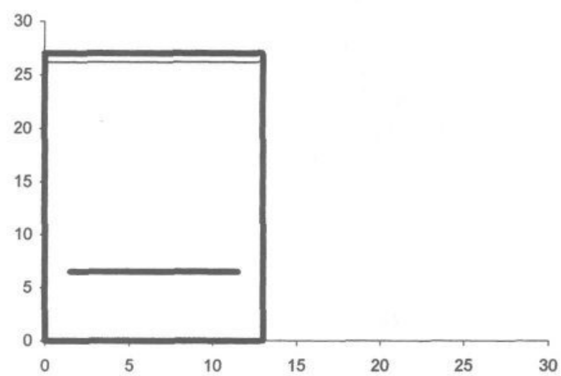


Figure 33-12 Distances to compression forces.

Check compression reinforcing against tension reinforcing

arm	20.10	in	531 /(0 + 26 + 0)
$M_{n\ comp}$	531	k-in	Compression block and reinforcing
T	26.4	k	0.44 * 60
$M_{n\ tens}$	531	k-in	20.10 * 26.40 Tension reinforcing

T — force in tension reinforcing, k



row 300

Figure 33-13 Beam cross-section used in appropriate pages to help in understanding and verifying math.

row 310

A B C D E F G H I J K L M N

MOMENT of INERTIA — I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4

E_c	3122	ksi	57000 * (3 * 1000)² /1000
n	9.29	*unitless*	*29000 /3,122*

For the Gross (Overall) Section

A*arm	0	in^3	$d' * n * -A_s$ 2.5 * 9.29 * 0.00
	84		$d * n * +A_s$ 20.5 * 9.29 * 0.44
Area deduct	0		2.5 * 0.00
	9		20.5 * 0.44
	0		$OH * t^2 /2$ 13.0 * 4.5² /2
	4739		width * d_OA² /2 13.0 * 27.0² /2
sum	4813	in^3	
Area	0	in^2	$-A_s * n$ 9.29 * 0.00
	4		$+A_s * n$ 9.29 * 0.4
	0		OH * t 13.0 * 4.5
	351		width * d_OA-s_area_-s_area_ 13.0 * 27.0 - 0.00 - 0.44
sum	355	in^2	
CG	13.57	in	4,813 / 354.65 from the top fiber

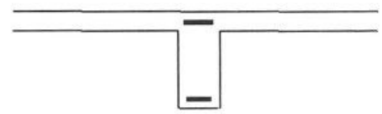
For Gross Section About the CG

Ad^2 conc	2	in^4	$(d\ OA * width) * (d\ OA /2 - Cg)^2$ (27.0 * 13.0) * (27.0 /2 - 13.57)²
	0		$(OH * t) * (t/2 - Cg)^2$ (0.0 * 4.5) * (78.0 /2 - 13.57)²
Ad^2 steel	0	in^4	$n * -A_S * (Cg - d')^2$ 9.29 * 6.00 * (13.6 - 2.5)²
	196		$n * A_s * (d - Cg)^2$ 9.29 * 0.00 * (20.5 - 13.6)²
Area	0		$-A_s * (Cg - d')^2$
deduct	21		$A_s * (d - Cg)^2$
I concrete	21323	in^4	$width * d\ OA^3 /12 + OH * tf^3/12$ 13 * 27³ /12 + 0 * 4.5³ /12
Ig	21500	in^4	2 + 0 + 0 + 196 - 0 - 21 + 21,323

To find the neutral axis NA_x for + and - reinforcing and the stress block:

$$w \times x/2 = n A'_s (x - d') + n A_s (d' - x)$$

This is solved with the quadratic equation.



row 320

Figure 33-14 Beam / T-beam cross section for Ad^2 / A = center of gravity from the top extreme fiber.

n — ratio of modulus of elasticity E_S / E_C, unitless

row 330

E_c — *modulus of elasticity of concrete, ksi*
d_OA — beam overal depth, inches

NOTE: use Ad^2 only. Do not rotate component areas around their own axes as in $bd^3/12$. Most moment of inertia calculations use $Ad^2 + bd^3/12$.

row 340

row 350

row 360

row 370

EFFECTIVE MOMENT of INERTIA I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4

For the Cracked Section

Where the equilibrium equation is:

C_c + C_s = T

Where **n - 1** deducts the area of compression concrete

For a rectangular beam:

b_w x x/2 + (n - 1) A'_s (x - d') = n A_s (d - x)

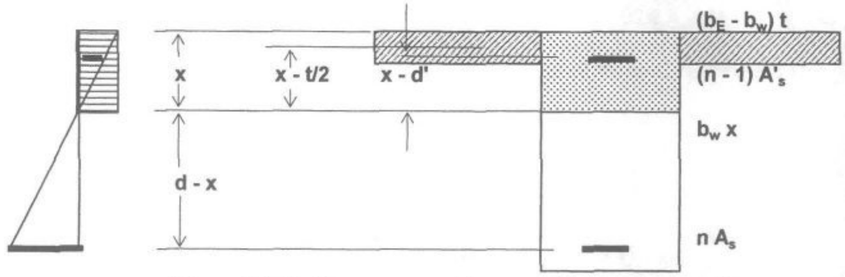


Figure 33-15 The component areas of the cracked section.

For a rectangular, spandrel, or T beam

flg logic 0 logic 1 if beam has a flange

stem	flange	compression reinforcing		tension reinforcing
$b_w x^2/2$ +	$(b_E - b_w)$ t (x - t/2) * flg logic +	(n - 1) A'_s (x - d') =	n A_s (d - x)	-n A_s (d - x) = 0
$b_w x^2/2$ +	$(b_E - b_w)$ t x * flg logic +	$(b_E - b_w)$ t (- t/2) * flg logic +	(n - 1) A'_s (x - d')	

a x^2	6.5 in	$b_w x^2/2$ + 6.5		
b x	4.1	$(b_E - b_w)$ t x * flg logic + 0	(n - 1) A'_s x 0.0	-n A_s (-x) 4.1
c	-83.8	$(b_E - b_w)$ t (- t/2) * flg logic + 0	(n - 1) A'_s (- d') 0.0	- n A_s d -84

row 400

NA_x	**3.290** in

[-b ± √ b² - 4 a c] /2a

[-4 + √ 4² - 4 * 6.5 * -84] /(2 * 6.5)

row 410

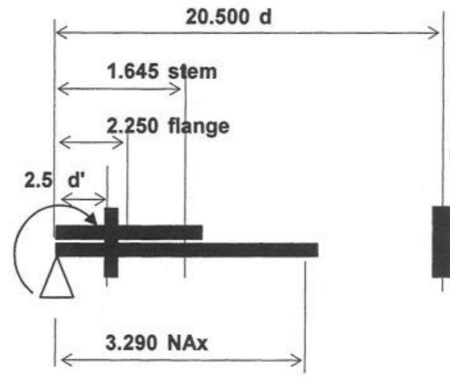
row 420

row 430

Two Methods of Checking NA_x

Take the moments of each component area about the extreme fiber in compression. Divide the sum of the moments by the area of the components. Compare this calculated NA_x to the NA_x calculated above.

	area	arm	area*arm
A's	0.00	2.500	0.000
stem	42.77	1.645	70.341
flange	0.00	2.250	0.000
As	4.09	20.500	83.786
sum	46.85		154.126
M/area			**3.290**

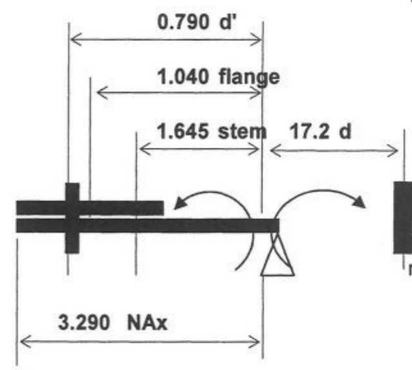


row 440

row 450

Take the sum of the area moments about the calculated NA_x to see if they are balanced.

	area	arm	area*arm
A's	0.00	0.790	0.000
stem	42.77	1.645	70.341
flange	0.00	1.040	0.000
As	-4.09	17.210	-70.341
			0.000



row 460

Figure 33-16 Moment of inertia is calculated as a balance of forces.

For the Cracked Section About NA_x

I conc. 154 In^4 w * NA_x^3 /3 + (b_E - w) * MINA(NA_x, t)^3 /12
13 *3.29³ /3 + (13 - 13) * MIN(3.29, 4.5)³ /12

$I_{cracked}$ I_{cr} , cracked moment of inertia

row 470

Ad^2 1211 In^4 n * A_s * (NA_x)^2 + n * A'_s *(NA_x - d_)^2
9.29 *0.44 *(20.5 - 3.29)² + 9.29 *0.00 *(3.29 - 2.50)²

Where M wk'g is the unfactored M at the section for which the deflection is computed

$I_{cracked}$ 1365 In^4 cracked section for ± reinforcing

For the Effective Moment of Inertia

fr	411	lb/in^2	$7.5\,f'_c{}^2$
M_{cr}	55	k-ft	fr * Ig /yt for rectangular section only
+M wk'g	22	k-ft	
	335752	In^4	$(M_{cr}/M_a)^3 * I_g$
	-19949	In^4	$[1 - (M_{cr}/M_a)^3] * I_{cr}$
Ie comp	315803	In^4	$(M_{cr}/M_a)^3 * I_g + [1 - (M_{cr}/M_a)^3] * I_{cr}$
I_g	21500	In^4	
I_e	21500	In^4	GOVERNS

row 480

row 490

REINFORCED CONCRETE BEAM
EXHAUST STACK

A B C D E F G H I J K L M N

CREEP vs. TIME in MONTHS — I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4

ρ'	0.00000	unitless	density of compression reinforcing	ρ'	density of compression reinforcing at midspan, unitless
	ξ	λ			
L_60	2.0	2.000	← multiply computed deflection by λ	ξ	time dependent factor for sustained load, 02 ACI 9.5.2.5
L_12	1.4	1.400			
L_6	1.2	1.200			
L_3	1.0	1.000		λ	multiplier for additional longterm deflection

row 500

Temperature Reinforcing Minimum

depth	**16**	in	depth not to exceed 16" for temperature reinforcing calculation
A_S req'd	0.346	in^2 @ 12"	
	0.432	in^2 @ 15"	
	0.518	in^2 @ 18"	
ρ temp	0.65	in^2/ft	entire slab 0.0020
ρ temp/2	0.32	in^2/ft	entire slab limit to 16" depth

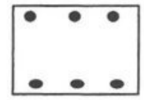
row 510

row 520

row 530

row 540

row 550



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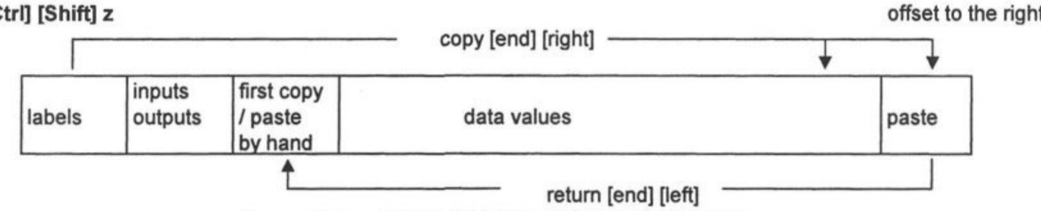
```
Sub Macro2()
'
' Macro2 Macro
' Macro recorded 9/11/2002 by Craig T. Christy                          row 560
'
' Keyboard Shortcut: Ctrl+Shift+Z
'
  Range("r13:r18").Select  <———— If you don't want to use this range, input your own selection.
  Selection.Copy
  Selection.End(xlToRight).Select
  ActiveCell.Offset(0, 1).Range("A1").Select
  ActiveSheet.Paste
  Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, SkipBlanks:= _
  False, Transpose:=False                                               row 570
  Selection.End(xlToLeft).Select
End Sub
```

Press **[Ctrl] [Shift] z**



row 580

Figure 33-17 GRAPHING VALUES FLOW DIAGRAM

Rectangular beam with variable +As tension reinforcing

fy	60	+As		3.54	aa	0.43	0.45	0.5	0.6	0.7	0.8	0.9	1
f'c	3		Mu prov	39.80		41.75	43.66	48.40	57.81	67.1	76.38	85.53	94.59
d'	2		M working	22		71	71	71	71	71	71	71	71
width	12		Mu req'd	31		100	100	100	100	100	100	100	100
d	36		Ig /100	215		142	142	142	143	144	145	146	146
depth_OA	38		I cr /100	14		21	21	22	25	28	31	34	36
A's	0		Ie /100	215		44	44	45	48	51	54	57	60
As	34		a * 50	39.819005		42.15686	44.11765	49.01961	58.8235	68.6	78.43	88.24	98.039

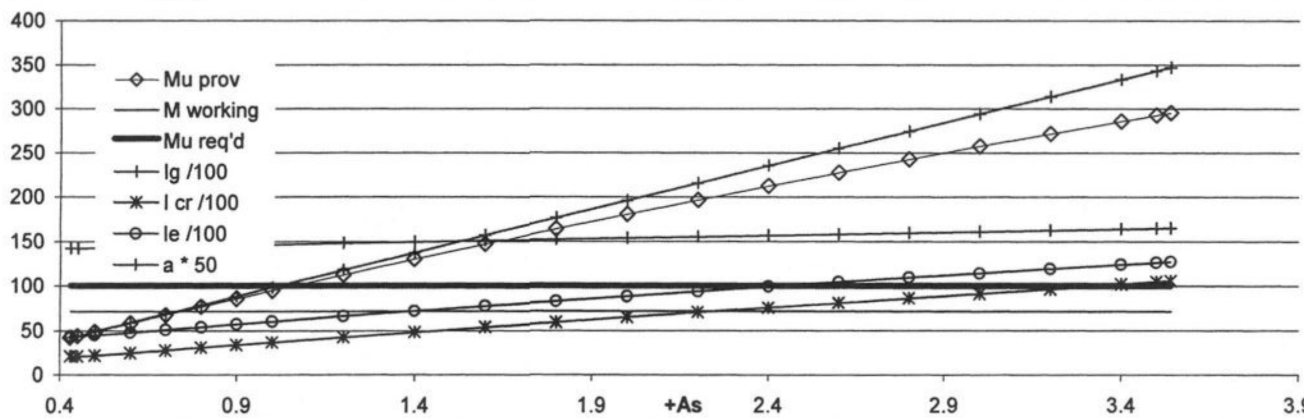
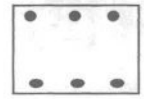


Figure 33-18 Rectangular beam +As compression reinforcing versus Mu Provided, Mu required, Ig, Icr, Ie.

row 610



33 Concrete Beam.xls

A	B	C	D	E	F	G	H	I	J	K	L	M	N
VERIFYING GRAPHS -- Continued						**I gross 21,500 in^4 / I cracked 1,365 in^4 / I effective 21,500 in^4**							
Rectangular beam variable -As' compression reinforcing													
fy	**60**	-As		**6.00**	aaa	**0.00**	**0.10**	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.80**
f'c	**3**		MU prov	40		292	294	296	297	299	301	303	307
d'	**2**		a * 50	40		343	333	323	313	304	295	286	269
b_w	**12**		MU req'd	31		250	250	250	250	250	250	250	250
d	**22**		Ig /100	215		165	166	167	168	169	169	170	172
depth_OA	**24**		I cr /100	14		104	104	103	103	103	102	102	101
A's	**varies**		Ie /100	215		106	105	105	105	104	104	104	103
As	**3.5**												

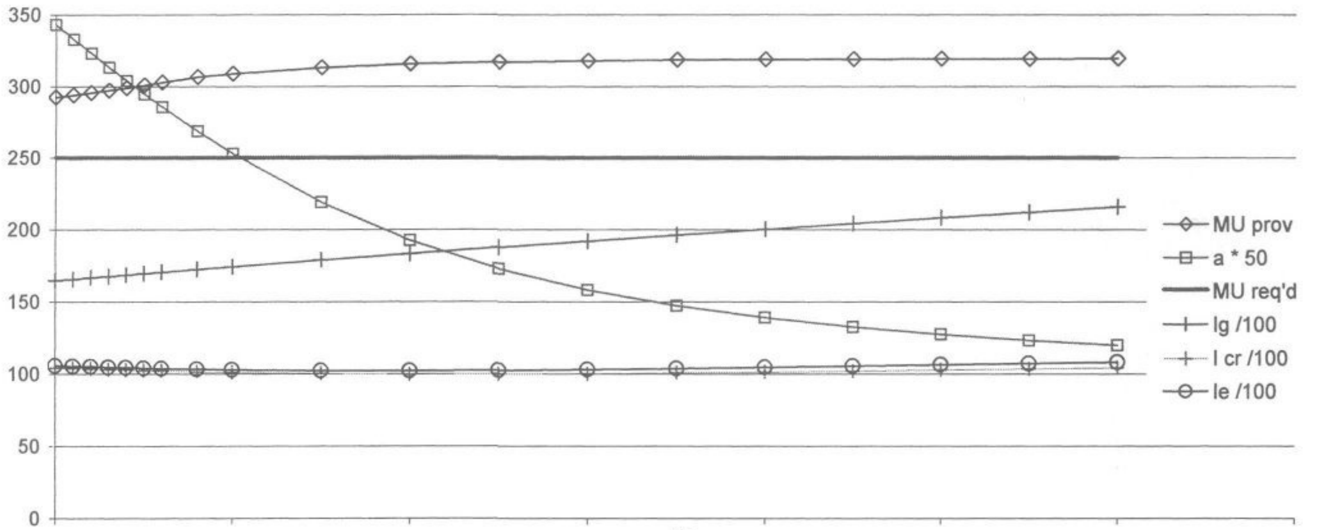


Figure 33-19 A's compression reinforcing versus Mu Provided, Mu required, Ig, Icr, Ie.

T-beam joist with variable spacing

fy	**60**	**joist spacing**	80	aa	12	13	14	15	20	25	30	35
f'_c	**3**	MU prov	39.80		257.29	260.14	262.72	265.06	273	277.9	281.1	283.39
d'	**2**	MU req'd	**250**		**250**	**250**	**250**	**250**	**250**	**250**	**250**	**250**
width	**12**	Ig /100	215.00		161.13	165.79	170.33	174.76	195	213.8	230.3	245.20
d	**22**	I cr /100	13.65		91.38	91.48	91.77	92.20	95.8	100.6	105.6	110.47
depth_OA	**24**	Ie /100	215.00		114.21	117.03	120.05	123.24	141	159.4	178.1	196.29
A's	**0**	a	7.964		58.824	55.490	52.157	48.824	35.3	28.24	23.53	20.168
As	**3**											
Length	**40**											
t	**4**											
c_	**varies**											
flange	**2**											

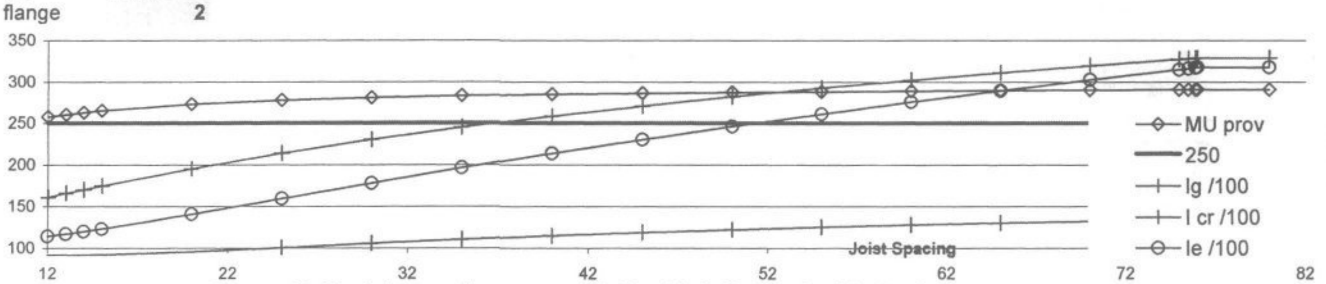
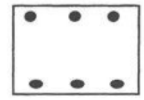


Figure 33-20 Joist spacing versus Mu Provided, Mu required, Ig, Icr, Ie.

row 670

REINFORCED CONCRETE BEAM
EXHAUST STACK



A	B	C	D	E	F	G	H	I	J	K	L	M	N
VERIFYING GRAPHS -- Continued													
T-beam variable +As tension reinforcing													
fy	60	+As		8.86	aa	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2
f'c	3		Mu prov	39.80		42.24	49.06	58.76	68.44	####	87.67	97.24	116.26
d'	2		Mu req'd	30.7		100	100	100	100	100	100	100	100
width	12		Ig /100	215.0012		201.8821	202.7001	203.864	205.023	206	207.3	208.5	210.74
d	22		I cr /100	13.648494		23.09306	26.40514	30.86259	35.0689	39.1	42.92	46.62	53.68
depth_OA	24		Ie /100	215.0012		83.62034	87.06423	91.77422	96.2889	101	104.9	109	116.92
A's	0		a * 100	79.638009		33.72549	39.21569	47.05882	54.902	62.7	70.59	78.43	94.118
As	varies												
Length	30												
t	4												
c_	30												
flange	2												

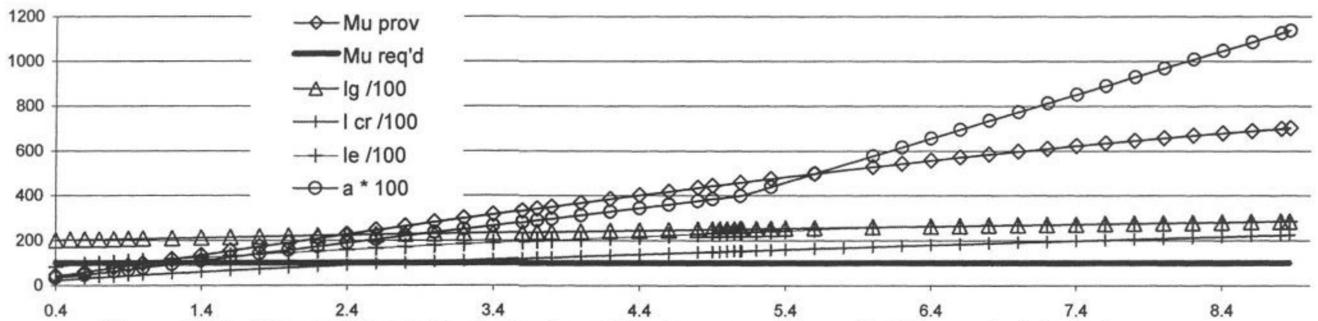


Figure 33-21 T-beam with variable +As tension reinforcing versus M_provided, Mu required, Ig, Icr, Ie.

T-beam variable -As' compression reinforcing

A	B	C	D	E	F	G	H	I	J	K	L	M	N
fy	60	+As		10.969	aa	0.1	0.2	0.3	0.5	1	1.5	2	2.11
f'c	3		Mu prov	39.80		143.93	146.41	148.96	154.25	####	#####	#####	207.37
d'	2		Mu req'd	30.7		100	100	100	100	100	100	100	100
width	12		Ig /100	215.0012		208.2046	209.461	210.7118	213.197	219	225.3	231.2	232.44
d	22		I cr /100	13.648494		7.919034	12.73429	17.35286	26.0852	45.6	62.83	78.33	81.556
depth_OA	24		Ie /100	215.0012		75.61118	80.81894	85.86392	95.5338	118	138.1	156.9	160.86
A's	2		a * 100	79.638009		117.1421	119.2233	121.359	125.799	138	151.7	167.3	170.93
As	varies		f'_y	0		0	0	0	0	0	0	0	5
Length	30												
t	4												
c_	30												
flange	2												

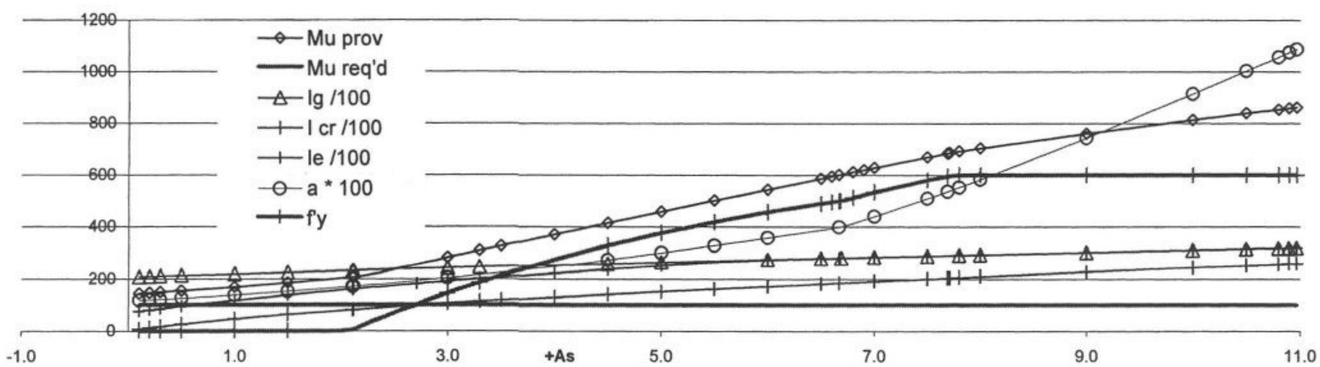
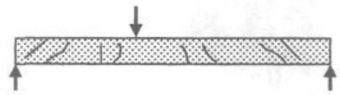


Figure 33-22 T-beam with variable -As' compression reinforcing versus M_provided, Mu required, Ig, Icr, Ie.

row 730



A B C D E F G H I J K L M N

PUNCHING SHEAR

P base PL	**263.6**	k	from bolt patterns template
ratio	**1.364**	unitless	from foundation design template
P_ult	**359.6**	k_ult	

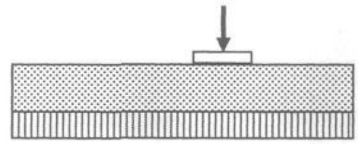


Figure 34-1 At-rest DL and LL values.

row 20

Bearing

F bearing	**0.750**	ksi	working stress value
A_req'd	351.5	in^2	263.6 k / 0.750 ksi
length	**7.5**	in	b_1
width	46.9	in	b_2 approximated

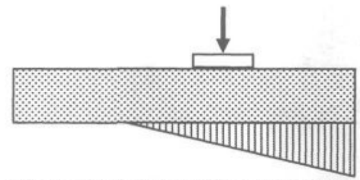


Figure 34-2 At-rest DL + LL + Wind values.

row 30

Punching Shear

f'_c	**3**	ksi	
d	**20.5**	in	
bo	150	in	(b_1+d/2 + b_2+d/2)*2 (7.50 + 46.86 + 20.5) * 2
Ao	3069	in^2	bo * d 20.5 * 150
b_o	6.25	unitless	ratio of long side to short side
V_c	**443.9**	k_ult	$(2 + 4/b_o) * (f'c*1000)^{0.5} * b_o * d /1000$ (11-35) (2 + 4 /6.25) * (3 * 1000)^0.5 * 150 * 20.5 /1000
a_s	**40**	unitless	
V_c	**1257.0**	k_ult	$(as * d /bo + 2) * (f'c*1000)^{0.5} * b_o * d /1000$ (11-36) (6.25 * 20.5 /150 + 2) * (3 * 1000)^0.5 * 150 * 20.5 /1000
V_c	**672.5**	k_ult	$A_o * 4 * (f'c * 1000)^{0.5}$ (11-37) 3,069 * 4 * (3 * 1000)^0.5 * /1000
V_c allow	443.9	k_ult	MIN(443.9, 1,257.0, 672)

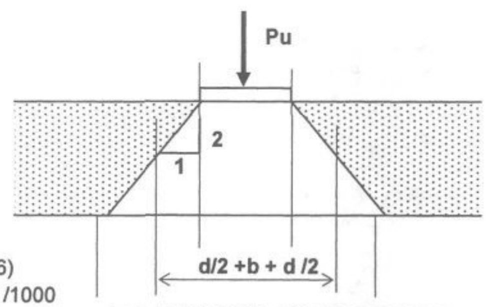


Figure 34-3 PUNCHING SHEAR PROFILE

V_u allow	377	k-ft_ult	V_c * 0.85
		OK	359.6 < 377.3

row 50

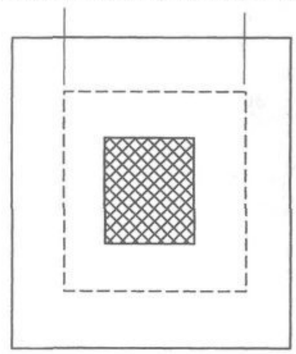


Figure 34-4 PUNCHING SHEAR PLAN VIEW

row 60

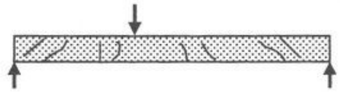
row 70

CONSULTING COMPANY

CONCRETE SHEAR
EXHAUST STACK

34

Christy
18:10
12/20/05



ENGINEERING with the SPREADSHEET

34 Concrete Shear.xls

A B C D E F G H I J K L M N

BEAM SHEAR

tributary	**6.5**	ft	distance from center of bearing to edge of footing
q loaded	**1.661**	ksf	
q	**1.121**	ksf	See ACI 11.3
V reqd	**18.1**	k_ult	
ratio	**1.364**	unit	
V_u reqd	24.7	k_ult	
d_	**20.5**	in	extreme fiber in compression to centerline of reinforcing
bw	**12**	in	width transverse to direction of load
f'_c	**3**	ksi	

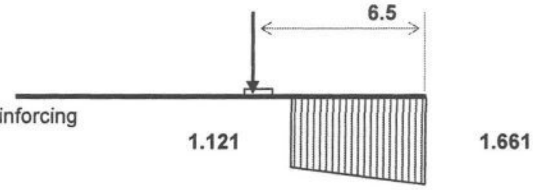


Figure 34-5 BEAM SHEAR PROFILE

Concrete

V_c	**26.9**	k	$2 * (f'_c*1000)^{0.5}$ * width * d ACI (11-3) 2 * (3*1000)^0.5 * 12 * 20.5 /1000
M_u	**30.7**	k-ft_ult	
F_y	**60**	ksi	flexural reinforcing strength
A_s	**0.31**	in^2	area of flexure reinforcing
p_w	0.0000	unitless	density of flexure reinforcing
V_u d /M_u	1.01	unitless	18.1 * 20.5 /12 /30.7
V_c	25.6	k_ult	$(1.9 * (f'_c * 1000)^{0.5}$ + 2500 * p_w * min(1, V_u * d / M_u)) * b_w * d (1.9 * (3 * 1000)^0.5 + 2500 * 0.0000 * MIN(1, 1.01)) *12 * 20.5 /1000
V_c	47.2	k_ult	$3.5 * (f'_c * 1000)^{0.05}$ * b_w * d_ 3.5 * (3 * 1000)^0.5 * 12 * 20.5 /1000)
V_c min	25.6	k_ult	MIN(47.2, 25.6)
V_c	**26.9**	k_ult	MAX(26.9, 25.6)

V_c allowable shear carried by concrete
shear + flexure only

V_s shear carried by stirrups

row 90

row 100

Stirrup

s	**8.0**	in.	stirrup/tie spacing <= d/2, 24" max spacing
F_y	**40**	ksi	stirrup/tie yield strength
A_v	**0.00**	in^2	sum of area for all bars to resist shear
V_s	0.0	k	A_v * F_y * d /s
V_s max	107.8	k.	$8 * (f'_c *1000)^{0.5}$ * width * d 8 * (3 * 1000)^0.5 * 12 * 20.5 /1000
V_s	**0.0**	k	MIN(0.0, 107.8)
F	**0.85**	unitless	
V_u allow	**22.9**	k_ult	F * (V_c + V_s) 0.85 * (26.9 + 0.0)

row 110

row 120

row 130

STACK DRAWINGS

EXHAUST STACK

Not included on CD-ROM.

A B C D E F G H I J K L M

The following drawings are not on the CD Rom.

In terms of construction, this is a small project. The stack drawings are used both to fabricate the stack and install it.

GENERAL NOTES

THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND CONDITIONS WITH THE STRUCTURAL/MECHANICAL DRAWINGS, AND EXISTING FIELD CONDITIONS.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL REQUIRED SAFETY PRECAUTIONS AND METHODS, TECHNIQUES, SEQUENCES, AND PROCEDURES REQUIRED TO PERFORM HIS WORK.

THE DRAWINGS INDICATE GENERAL AND TYPICAL DETAILS OF CONSTRUCTION. WHERE CONDITIONS ARE NOT SPECIFICALLY INDICATED BUT ARE SIMILAR IN NATURE TO THE DETAILS SHOWN, SIMILAR DETAILS OF CONSTRUCTION SHALL BE USED, SUBJECT TO REVIEW AND APPROVAL OF THE ENGINEER.

CHANGES IN CONSTRUCTION DETAILS, MEMBERS, AND ETC. MUST BE CONFIRMED BY WRITTEN MEMO AND/OR SKETCH FROM THE ENGINEER.

THIRD PARTY SPECIAL INSPECTION WILL BE PROVIDED FOR REINFORCING STEEL AND CONCRETE. SPECIAL INSPECTION OF ANCHOR BOLT ASSEMBLIES WILL BE PROVIDED BY THE ENGINEER.

LOADS

WIND ——— 150 MPH
SEISMIC ——— U.B.C. ZONE 3, I =1.25, R = 2.2

CORROSION ALLOWANCE – 1/16"

8.35" EXPECTED DEFLECTION AT THE TOP OF THE STACK DUE TO VORTEX SHEDDING AT 36 MPH

FOUNDATIONS

REFER TO GEOTECHNICAL ENGINEER'S SPECIFICATIONS FOR SOIL PREPARATION AND FILL.

DESIGN SOIL ALLOWABLE BEARING IS 2000 PSF. STACK FOOTING TO BE FOUNDED FIRM ORIGINAL SOIL OR GRANULAR BACKFILL COMPACTED TO 95% MODIFIED PROCTOR DENSITY.

THE BOTTOM OF ALL FOOTINGS AND OTHER CONCRETE SHALL BE 18" MINIMUM BELOW FINISHED GRADE FOR FROST DEPTH PROTECTION.

STRUCTURAL STEEL AND MISCELLANEOUS IRON

ALL HOT ROLLED STRUCTURAL STEEL SHALL CONFORM TO ASTM A36 OR A992 AND TO U.B.C. STANDARDS.

ALL FABRICATION, ERECTION, AND IDENTIFICATION OF STRUCTURAL STEEL SHALL CONFORM TO AISC AND U.B.C. SPECIFICATIONS AND STANDARDS.

EMBEDS MUST BE ACCURATELY PLACED AND SECURED TO RESIST FOOT TRAFFIC AND CONCRETE PLACEMENT.

USE WELD METAL WITH A CHARPY V-NOTCH TOUGHNESS OF 20 OR GREATER AT 70° F.

THIS INCLUDES WELDING MATERIAL SUCH AS: E70TG-K2, E71T-8, E7018

THIS DOES NOT INCLUDE: E70T-4

PLACE 1"± STEEL SHIMS ON CONCRETE BEFORE SETTING THE STACK. JACKING / LEVELING NUTS ARE NOT ALLOWED.

CONCRETE - CAST IN PLACE

PROVIDED CONCRETE STRENGTH IS 3000 PSI WITH 3% TO 5% AIR ENTRAINMENT, 4 1/2" ± 1" SLUMP. PROVIDE LIGHT BROOM FINISH.

CONCRETE MIXING, PLACING, AND CURING SHALL CONFORM TO THE ACI MANUAL OF CONCRETE PRACTICE AND ACI SPECIFICATIONS.

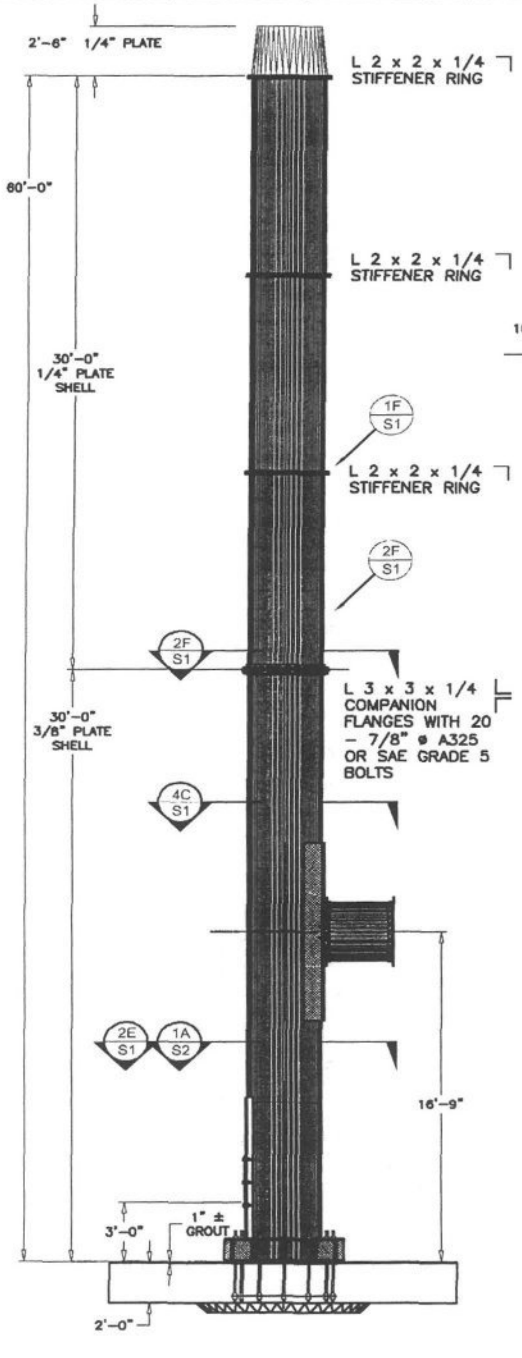
CONCRETE REINFORCING STEEL

ALL REINFORCING STEEL FOR CONCRETE SHALL BE ASTM GRADE 60.

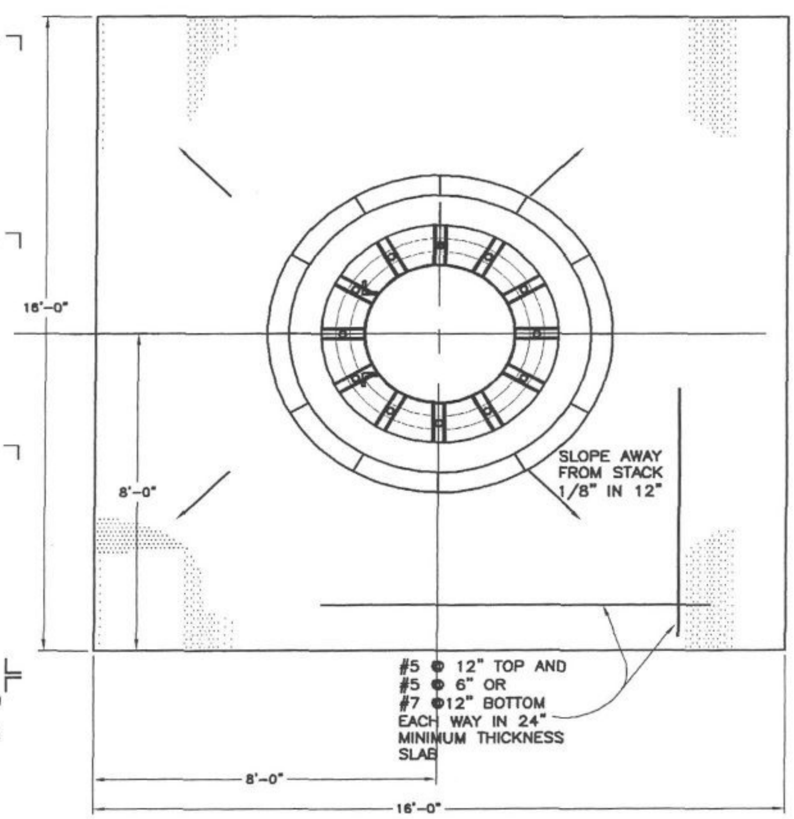
ALL REINFORCING STEEL SHALL BE ACCURATELY AND SECURELY PLACED PRIOR TO PLACING CONCRETE.

MINIMUM CONCRETE COVER FROM SURFACES SHALL BE:
3" +/- 1/4" TO THE BOTTOM OF FOOTINGS
2" +/- 1/4" TO EARTH OR WEATHER FACE

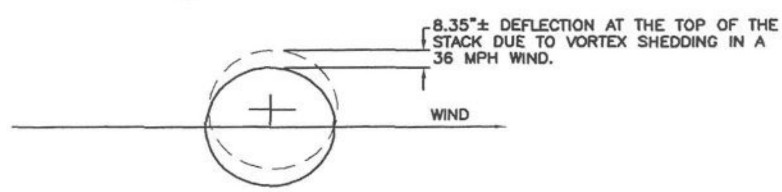
4B/S1 STACK VIEW 1/4" = 1'-0"



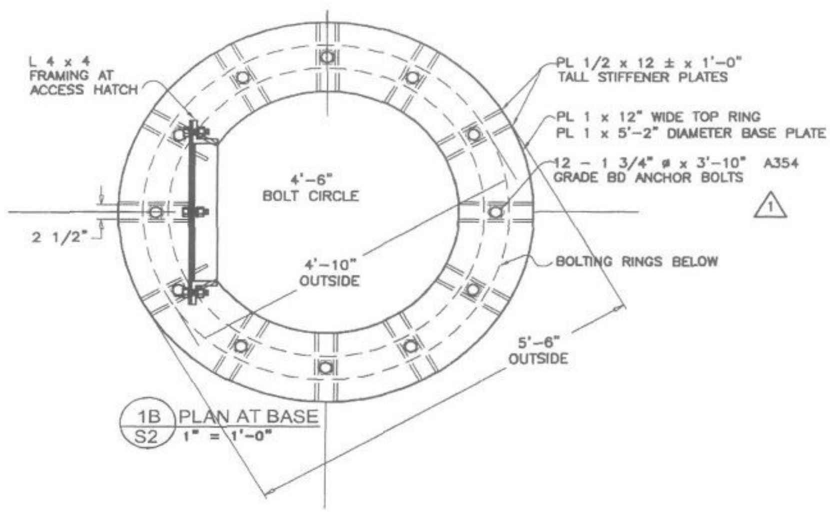
4C S1 STACK ELEVATION
1/4" = 1'-0"



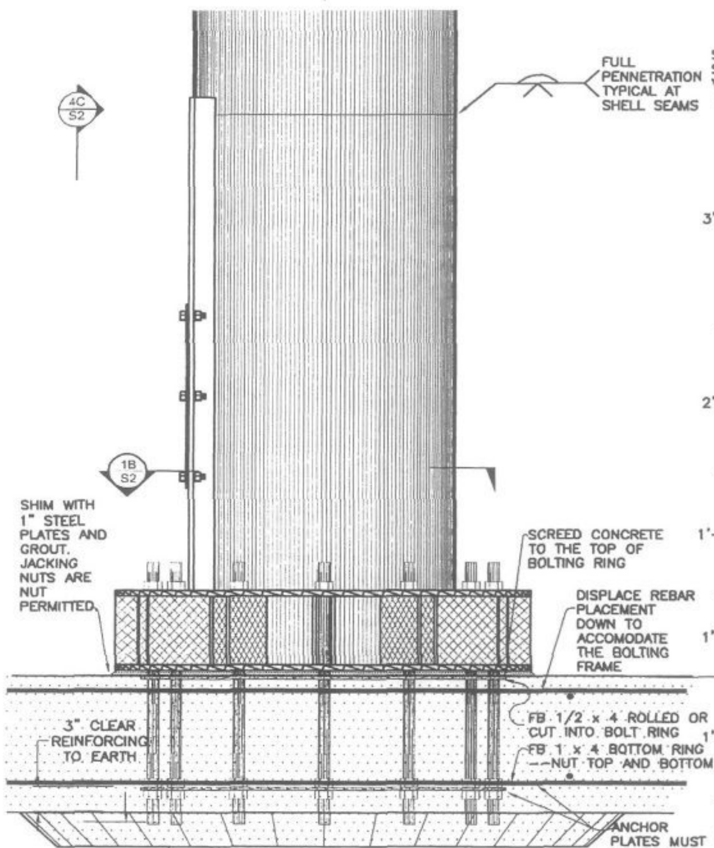
2E S1 FOUNDATION PLAN VIEW
1/2" = 1'-0"



VORTEX SHEDDING

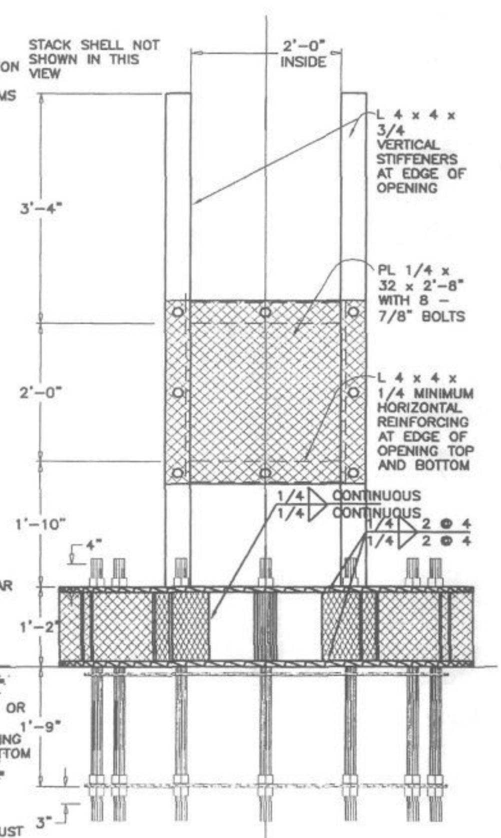


1B S2 PLAN AT BASE
1" = 1'-0"



4B S2 ELEVATION AT BASE
1" = 1'-0"

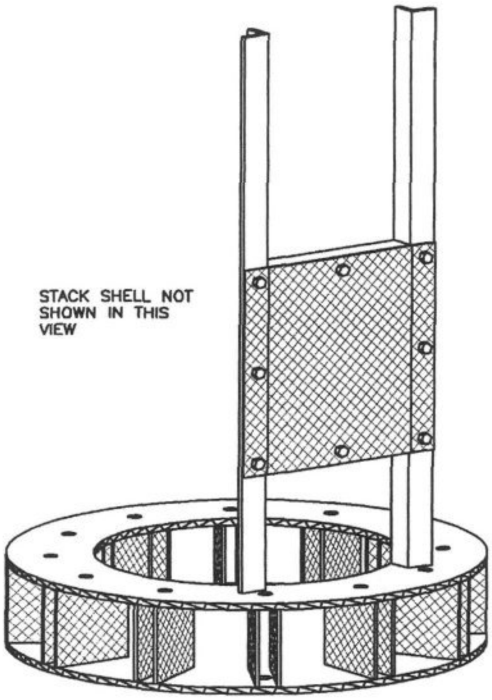
211



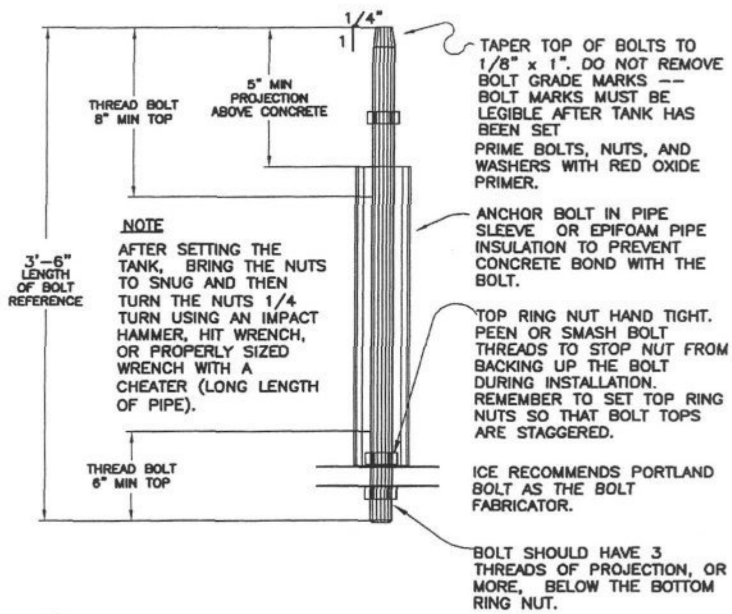
4C S2 ELEVATION AT BASE
1" = 1'-0"

STACK DRAWINGS
EXHAUST STACK

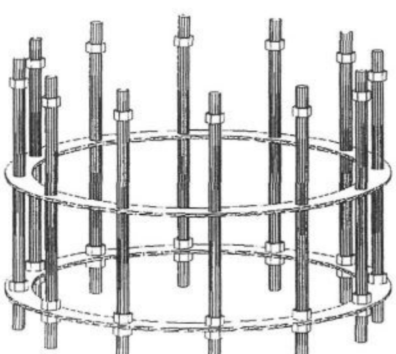
Not included on CD-ROM.



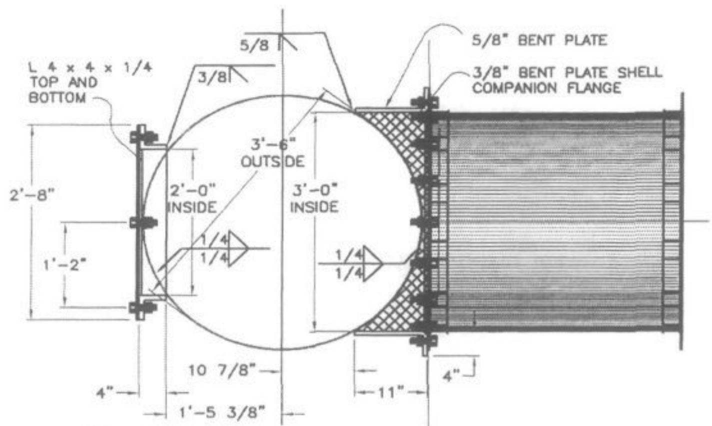
3D / S2 ACCESS HATCH VIEW 1" = 1'-0"



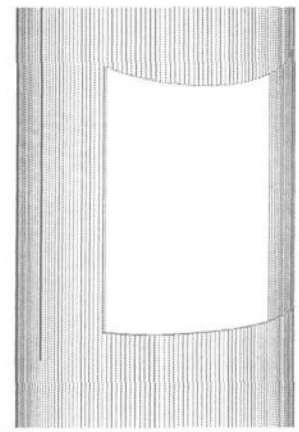
3E / S2 ANCHOR BOLT DETAIL NO SCALE



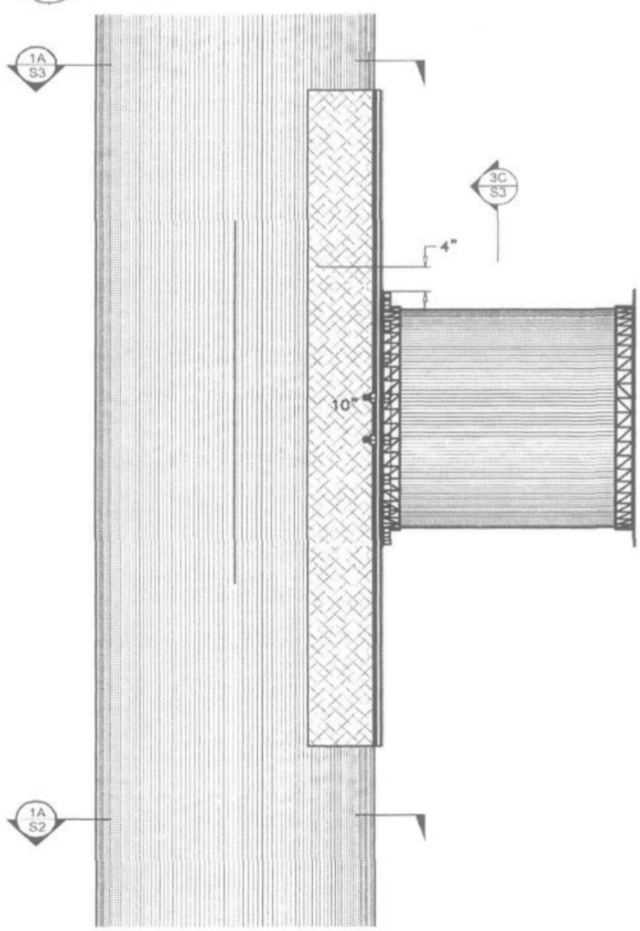
4D / S2 BOLT RING VIEW 1" = 1'-0"



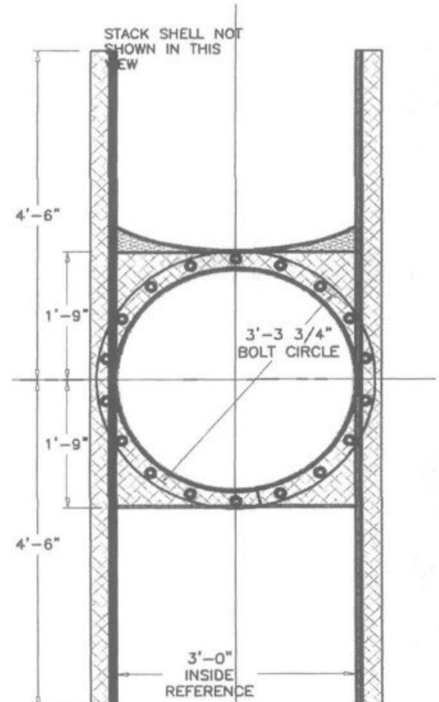
1A / S3 PLAN AT INTAKE
1" = 1'-0"



2C / S3 INTAKE VIEW
1" = 1'-0"



4C / S3 ELEVATION AT INTAKE
1" = 1'-0"

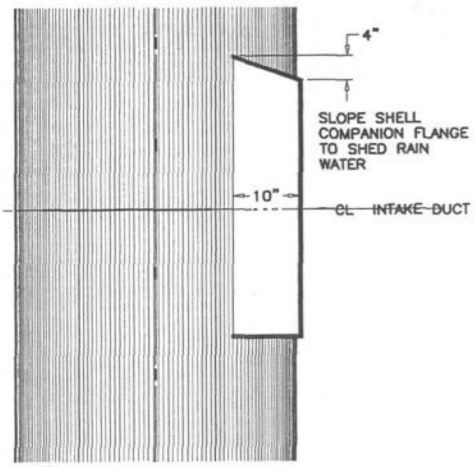


3C / S3 ELEVATION AT INTAKE
1" = 1'-0"

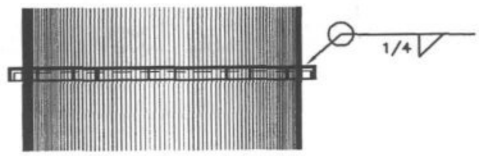
STACK DRAWINGS
EXHAUST STACK

Not included on CD-ROM.

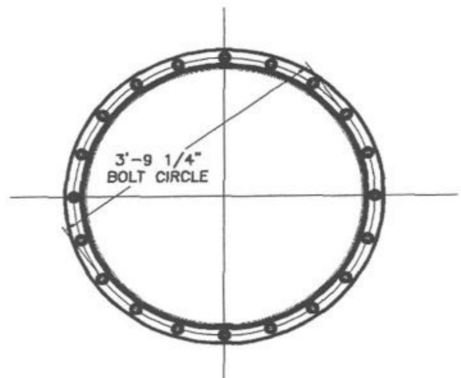
A B C D E F G H I J K L M N



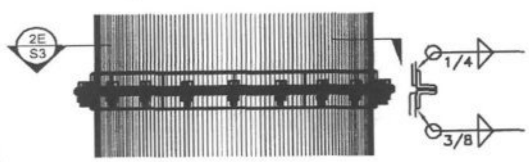
2D / S3 INTAKE FACE PLATE DETAIL
1" = 1'-0"



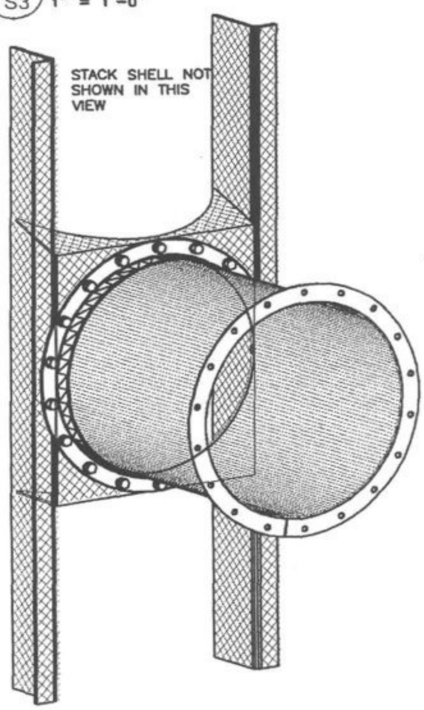
1E / S3 SHELL STIFFENER DETAIL
1" = 1'-0"

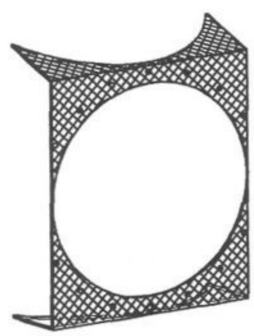


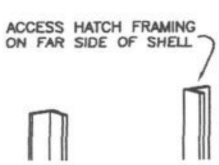
2E / S3 PLAN AT COMPANION FLANGES
1" = 1'-0"



3E / S3 COMPANION FLANGES DETAIL
1" = 1'-0"







4D / S3 INTAKE VIEW
1" = 1'-0"

CONSULTING COMPANY

NOTES

ENGINEERING with the SPREADSHEET

A	B	C	D	E	F	G	H	I	J	K	L	M	N

20

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50

60

PART 4:

ELEVATED STORAGE TANK

CONSULTING COMPANY

NOTES

ENGINEERING with the SPREADSHEET

A B C D E F G H I J K L M N

ELEVATED STORAGE TANK
INTRODUCTION

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Not included on the CD-ROM

A B C D E F G H I J

ELEVATED STORAGE TANK

Figure 36-1 The tank.

CONSULTING COMPANY

ELEVATED STORAGE TANK
INTRODUCTION

36

Not included on the CD-ROM

ENGINEERING with the SPREADSHEET

A B C D E F G H I J

ELEVATED STORAGE TANK

This is a bulk storage tank for high purity liquid nitrogen located in a seismic zone III somewhere in the western United States.

At water test weight, the tank and contents weigh about 6,000,000 Lbs. supported at 15 ft above grade. The actual product weighs 80% of what water weighs. Seismic design is based upon structure dead load and product live load. Wind design is for an empty tank but seismic governs. When the tank is in service, the upper deck is allowed to deflect and/or settle about 1/8" in 30 ft.

Settlement constraints are tight and fairly difficult to meet. In the past, these structures have been a 2 ft thick deck located on a maze of walls. This makes it easier to solve the settlement and seismic issues. But, the maze of walls creates unusable space below the deck. Also, liquid nitrogen is dangerous -- a release of liquid nitrogen in a confined area can easily kill someone. You need roughly 17.5% oxygen content in the air to be able to breathe and the vaporizing nitrogen can easily displace enough oxygen to suffocate you, and it's odorless.

An open frame below the tank leaves a well ventilated, usable space.

The design of this tank went through several iterations and input from the contractor and soils engineer. This project was not, however, value engineered. How the contractor's estimator can deliver a better design than the engineer is beyond me.

Our goals were:
- Safety when in use
- Structural settlements
- Time for construction
- Financial investment in the foundation
- Utility of the space below the tank

The final three iterations eliminated walls which are expensive and time consuming and all battered piles which didn't work well in this situation. The final design uses the bending and compression of the soil at the piles to resist seismic lateral force. 21 of the 55 pilings run up through the pile cap to support the deck.

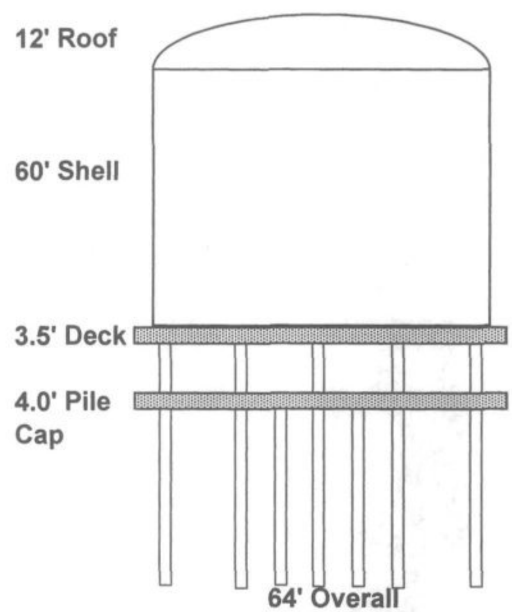

Figure 36-2 The design elevation diagram of the tank, deck, pile cap, and piling.

Pilings are filled with concrete and reinforcing cages to create composite columns. The deck and pile cap are reinforced with #7's at 4" each way. The last, important, design issue was how to create a moment joint between the piling and the pile cap and between the piling composite columns at the pile cap and deck.

A B C D E F G H I J

ELEVATED STORAGE TANK -- Continued

Iteration 1 is the most obvious. Run mat rebar through the columns as we normally do with beam reinforcing through a column cage. This entails torching holes in the steel pile and running #7's through the holes and the cage. This was going to be difficult and did not address the issue of punching shear.

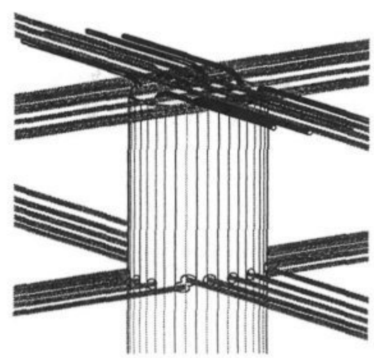

Figure 36-3 The torched piling concept.

Iteration 2 is the second most obvious. Create collars to which A706 rebar can be welded and the punching shear can be resolved. Collars are cut from 3/4" plate and require a 1" x 1" backup bar below the collar for strength and welding.

The collar idea requires lots of fabrication and extensive field welding. To use collars would increase the construction time by weeks.

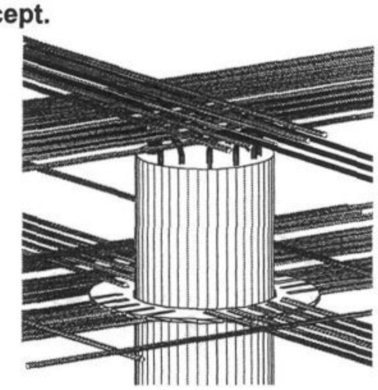

Figure 36-4 The pile collar concept.

Iteration 3 is obvious -- use 3/4" x 6" headed weld studs for shear and let the rebar mats confine the pile columns. Much of the moment is transferred between the slab and column through a lopsided shear mechanism.

Installation of the weld studs at grade required about three hours.

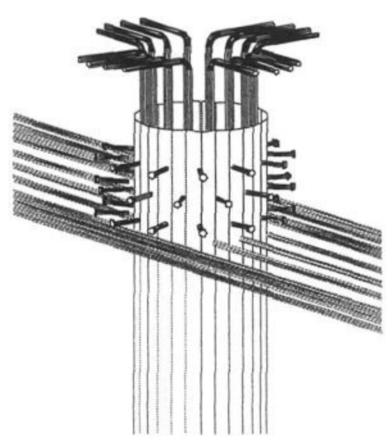

Figure 36-5 Weld studs to resist shear.

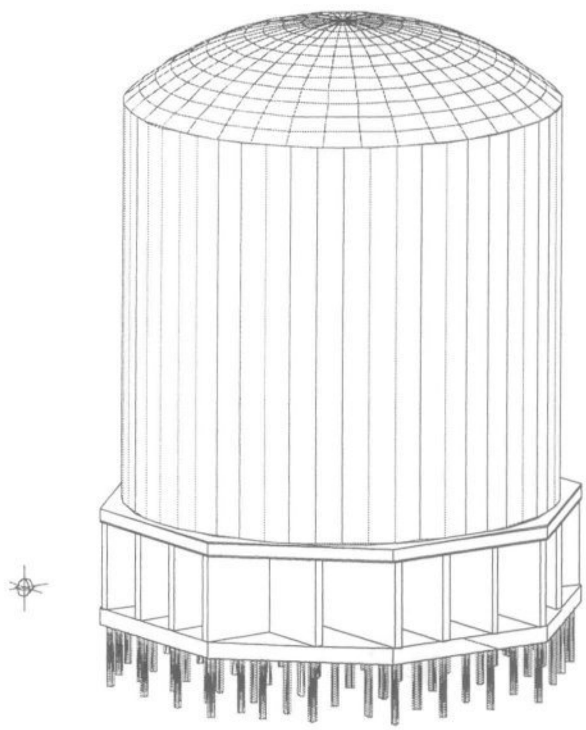

Figure 36-6 Tank structural support walls and slabs.

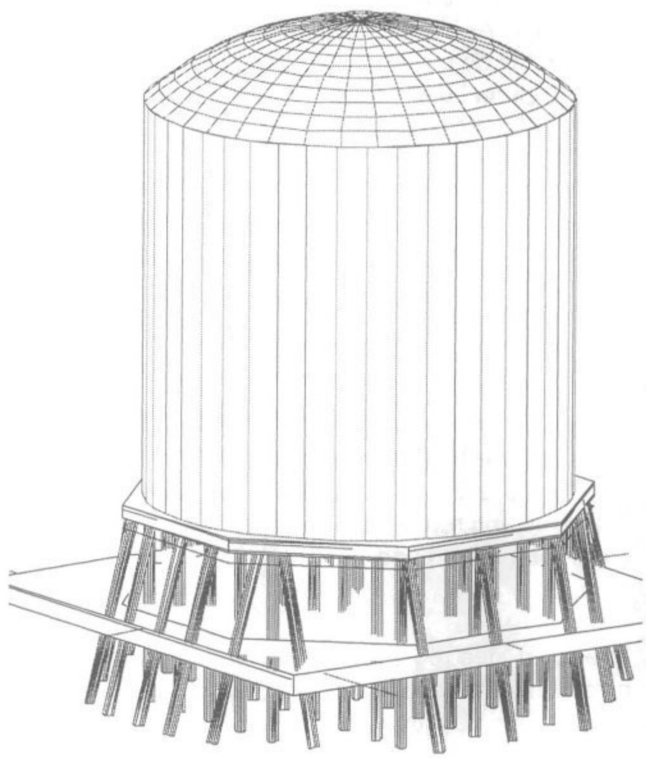

Figure 36-7 Tank on battered piling.

A	B	C	D	E	F	G	H	I	J
ELEVATED STORAGE TANK -- Pile Driving									

Figure 36-8 The pile driver setup.

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NOTES

ENGINEERING with the SPREADSHEET

A B C D E F G H I J K L M N

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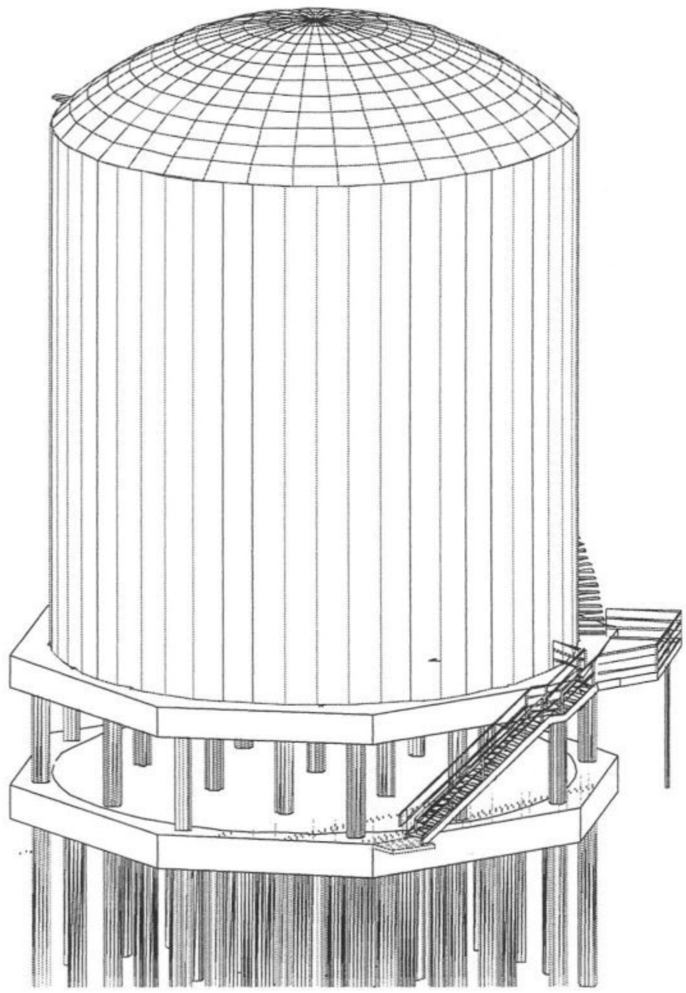
STRUCTURAL CALCULATIONS

for

TANK SUPPORT



Prepared by:
Craig T. Christy, P.E.
December 3, 2002

CONSULTING COMPANY

Wind = 80 mph, exposure C tank empty
Seismic zone 3, R = 2.9, T > 0.06 seconds   tank full
Seismic safety factor = 1.25
Seismic governs

Minimum reinforcing for flexural members subject to seismic forces per ACI 21.3.2 also meets effective moment of inertia to limit deflections in at-rest water test.

Pile lateral deflection is permitted to be as great as 1" to develop lateral resistance to seismic event(s).

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SEISMIC CALCULATIONS
TANK SUPPORT

38

Christy

18:14
12/20/05

ENGINEERING with the SPREADSHEET

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A	B	C	D	E	F	G	H	I	J	K	L	M	N

SEISMIC CALCULATION WORKSHEET V = 0.304 W_Ultimate = 0.217 W_working stress

Z	0.3 unit	seismic zone factor	ZONE	1	2A	2B	3	4	
soil	S_D	soil profile type	Z	0.075	0.15	0.2	0.3	0.4	

Copy clip table values to reduce transcription errors.

SOIL PROFILE TYPE		blows/ft	logic	
S_A	Hard rock		0	
S_B	Rock	>50	0	
S_C	Very dense soil & soft rock	15 to	0	row 20
S_D	Stiff soil	<15	5	
S_E	Soft soil		0	
S_F	Soil requiring evaluation		0	
			5	

SEISMIC COEFFICIENT C_A UBC TABLE 16 Q

SOIL TYPE	SEISMIC ZONE FACTOR, Z 0.075	0.150	0.200	0.300	0.400
S_A	0.06	0.12	0.16	0.24	0.32
S_B	0.08	0.15	0.20	0.30	0.40
S_C	0.09	0.18	0.24	0.33	0.40
S_D	0.12	0.22	0.28	0.36	0.44
S_E	0.19	0.30	0.34	0.36	0.36
S_F	Soil requiring evaluation				

row 30

C_a	0.36 unitless

C_a The coefficient that defines the short period ground motion for structures with a fundamental period < C_v /2.5 C_a . row 40

SEISMIC COEFFICIENT Cv 97 UBC TABLE 16 R

SOIL TYPE	SEISMIC ZONE FACTOR, Z 0.075	0.150	0.200	0.300	0.400	logic	
S_A	0.06	0.12	0.16	0.24	0.32	0	
S_B	*0.08*	*0.15*	*0.20*	*0.30*	*0.40*	*0*	
S_C	0.13	0.25	0.32	0.45	0.56	0	
S_D	0.18	0.32	0.40	0.54	0.64	5	
S_E	0.26	0.50	0.64	0.84	0.96	0	row 50
S_F	Soil requiring evaluation					0	
						5	

C_v	0.54

C_v The coefficient that defines the longer period constant velocity ground motion.

The first five soil profile types are based upon soil *shear wave velocity. Values for SF require a soil specific evaluation to establish site coefficients.*

row 60

A B C D E F G H I J K L M N

NEAR-SOURCE FACTOR Na 97 UBC TABLE 16 S ZONE 4 CALCULATION V = 0.304 W_Ultimate = 0.217 W_working stress

Distance **5** Km 3.11 miles -- Closest distance to known seismic source in Km

type **C** Seismic source type

The near source factors **Na** and **N_v** apply to Zone 4 calculations UBC 1628 Symbols and Notations

SEISMIC SOURCE TYPE 97 UBC TABLE 16 U

A Faults that can produce large magnitude events and have a high rate of activity

B All faults other than A or C

row 70

C Faults that are not capable of producing large magnitude events and have a low rate of activity

CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE (Km)

	2.00	**5.00**	**10.00** and greater	
SEISMIC	0	1	1	
SOURCE	1	0	0	
TYPE	0	1	0	
A	1.50	1.20	1.00	1.00
B	1.30	1.00	1.00	1.00
C	1.00	1.00	1.00	1.00

logic 0 0 4 4

N_a 1.00

N_a The acceleration based factor for short period structures

choose 5 10 5 hlookup 1 1 5 1

NEAR-SOURCE FACTOR Nv 97 UBC TABLE 16 T ZONE 4 APPLICATION

Distance **5** Km 3.11 miles -- Closest distance to known seismic source in Km

type **C** Seismic source type

CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE (Km)

	2.00	**5.00**	**10.00**	**15.00** and greater
SEISMIC	0	1	1	1
SOURCE	1	0	0	0
TYPE	0	1	0	0
A	2.00	1.60	1.20	1.00
B	1.60	1.20	1.00	1.00
C	1.00	1.00	1.00	1.00

row 90

logic 0 0 4

N_v 1.00

NEAR-SOURCE CALCULATIONS

C_a	**0.36**	unitless	soil type factor 97 UBC Table 16Q
N_a	**1.00**	unitless	near source factor from above
C_a*N_a	0.36	unitless	**C_a*N_a** in Zone 4 UBC 1628 Symbols IF(0.3 zone = 0.4 , 1.00 * 0.36 , 0.36)
C_v	**0.54**	unitless	seismic coefficient 97 UBC Table 16R
N_v	**1.00**	unitless	near source factor from above
C_v*N_v	0.54	unitless	near source factor **N_v** used in Zone 4 IF(0.3 = 0.4 , 0.54 * 1.00Nv , 0.54) see UBC 1628 Symbols and Notations

N_v The velocity based factor for ground motion periods > 1 second

4 choose 5 10 5 hlookup 1 1 5 1

Check with the local Building Official as to which seismic zone and near source factors may be required.

Parts of the Oregon coast have been reclassified to Zone 4. More of western Oregon and Washington may be reclassified to Zone 4 in the future.

row 110

A B C D E F G H I J K L M N

SEISMIC CALCULATION WORKSHEET -- Continued V = 0.304 W_Ultimate = 0.217 W_working stress

Z	**0.3**	unitless	zone acceleration factor from above	
soil	**SD**	alpha	soil type Stiff soil	
R	**2.9**	unitless	**TABLE 16-P - R FACTORS for NONBUILDING STRUCTURES 11. All other structures not otherwise covered.**	
I	**1.25**	unitless	importance factor	
h_n	**75**	ft	building height	
C_t	**0.030**	unitless	building period factor based upon construction style 97 UBC 1630.2.2	

Ct = 0.030 for reinforced concrete moment-resisting frames and eccentrically braced frames.

R The structure response factor based upon the structure configuration, stiffness, and force amplification characteristics in an earthquake leading to a ratio of seismic base shear to the ability of the structure to absorb energy and inelastic deformations without collapse.

Note that the structure may be rendered useless by the seismic event that it was designed for under this system. However, some designs account for inelastic deformations and the continued use of the structure with or without repairs.

I importance factor

T	0.765	seconds	Ct * hn^0.75 . (30-8) natural period .. 0.030 * (75.0^0.75)	T > 0.06 Flexible nonbuilding structure .. use UBC 1630.5 V = Ft + sum Fi .. row 130
V rigid	0.315	* W	0.7 * C_a * I * W (34-1) 0.7 * 0.36 * 1.25 * W	V lateral force, * W
V flexible	0.304	*W	C_v * I / (R * T) *W (30-4) 0.54 * 1.25 / (2.9 * 0.765) * W	
V	0.304	*W	flexible structure ..	

1630.2.2
Ct = 0.035 for steel moment resisting frames
Ct = 0.030 for reinforced concrete moment-resisting frames and eccentrically braced frames.
Ct = 0.020 for all other buildings

row 140

Vmax	0.388	*W	2.5 * C_a * I / R *W (30-5) 2.5 * 0.36 * 1.25 / 2.9 * W	maximium lateral force
Vmin	0.050	*W	0.11 * C_a * I * W (30-6) 0.11 * 0.36 * 1.25 * W	this value sets the lower bounds for long period structures **C_a** is multplied by **N_a** in Zone 4 calculations
Structure	**1**	input	**0** = building structure 0.8 in (30-7), **1** = non building structure 1.6 in (34-3)	row 150
Vmin_4a	0.252	*W	0.56 * C_a * I *W (34-2) 0.56 * 0.36 * 1.25 * W	for non-building structures **C_a** is multplied by **N_a** in Zone 4 calculations
	1	logic	for flexible nonbuilding structures 1634.5	

row 160

A B C D E F G H I J K L M N

SEISMIC CALCULATION WORKSHEET -- Continued V = 0.304 W_Ultimate = 0.217 W_working stress

	1.00	unitless	near source factor for Zone 4 calculations
Vmin_4b	0.207	*W	0.8 in (30-7), 1.6 in (34-3) * Z * N_v * I / R * W (34-3)
			1.6 * 0.30 * 1.00 * 1.25 / 2.9 * W
zone	0	logic	0.3 = 0.4 is not Zone 4 ..

$V\_applied_u$	**0.304**	*W_ultimate strength
		T > 0.06 Flexible nonbuilding structure ..

$V\_applied_w$	**0.217**	*W_working stress
		T > 0.06 Flexible nonbuilding structure ..

TABLE 16-P - R FACTORS for NONBUILDING STRUCTURE

1.	Tanks, vessels or pressurized spheres on braced or unbraced legs	2.2	2.0
5.	Inverted pendulum type structures	2.2	2.0
	Cantilevered column building systems		
9.	Signs and billboards	3.6	2.0
11.	All other structures not otherwise covered.	2.9	2.0

Non-Building Structures at Grade UBC 1634

V **0.217** *W applied

For nonbuilding structures at / or below grade

weight	**60000**	lbs	gross weight of item
CG	**240**	in	
M_ot	3131288	in-lbs	0.217 g * 240.00" * 60,000 lbs
bolt_brg	**90**	in	bolt to bearing to resist overturning
CG_rt	**30.00**	in	arm in plan view to cg of gross weight
M_rt	1530000	in-lbs	0.85 * 60,000 lbs* 30.00 in
Bolts t	**2**		
tension	8896	lbs	(3,131,288 - 1,530,000) in-lbs / 90.00 in / 2 bolts
Bolts v	**4**		
shear	3262	lbs	0.217 * 60,000 lbs / 4 bolts

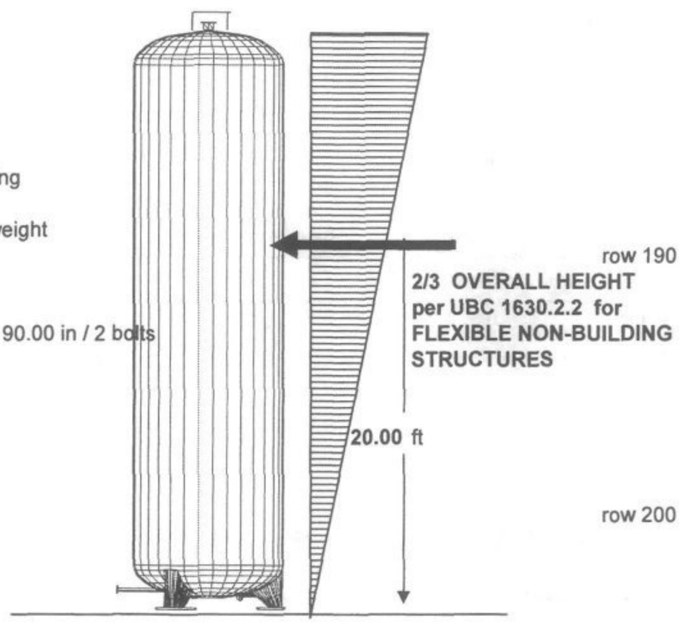

Figure 38-1 FLEXIBLE STRUCTURE

######

A B C D E F G H I J K L M N

SEISMIC ASCE/SEI 7-02 and 7-05

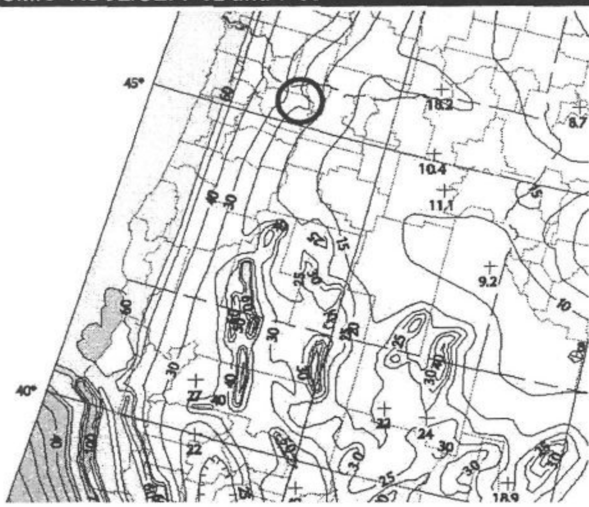

Figure 39-1 This is the map for the 1.0 second spectral response acceleration.

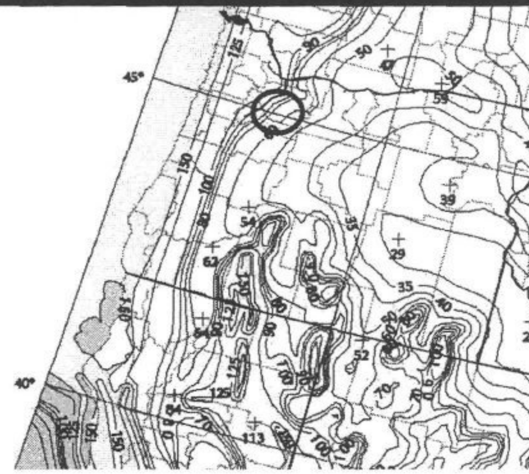

Figure 39-2 This is the map for the 0.2 second spectral response acceleration.

Note: USGS maps are 5% of Critical Damping, Site Class B. Near source factors Na and Nv are accounted for in the seismic maps and lookup tables

ASCE 7-02 and 7-05 callouts are presented as 7-02 / 7-05 for ease of cross-referencing

Site Class	D	Site Classification Tables 1-1, 9.13 and 9.14 / Tables 1-1 and 11.5-1		
D Stiff soil		600 < vs < 1,200 15 < N < 50 1,000 < su < 2,000		
SUG	III	Seismic Use Group Table 9.1.4 / Table 1-1		row 40
I_E	1.25 unitless	occupancy importance factor		

S_S	0.9692 g ultimate	mapped maximum spectral response acceleration at short periods for Site Class B		
F_a	1.1123 unitless	Velocity Based Site Coefficient for short periods Table 9.4.1.2.4a / Table 11.4-1		
S_{MS}	1.0781 g ultimate	1.1123 * 0.9692	F_a S_S Eq. 9.4.1.2.4-1 / Eq. 11.4-1	
S_{DS}	0.7187 g ultimate	2/3 1.0781	2/3 S_{MS} design response accelleration at short periods Eq. 9.4.1.2.5-1 / Eq. 11.4-1	
S_1	0.3584 g ultimate	mapped maximum response accelleration at T = 1.0 sec Table 9.4.1.2.4b / Table 11.4-2		row 50
F_v	1.6832 unitless	Velocity Based Site Coefficient at T = 1.0 sec Table 9.4.1.2.4b / Table 11.4-2		
S_{M1}	0.6033 g ultimate	1.6832 * 0.3584	F_a S_1 Eq. 9.4.1.2.4-1 / Eq. 11.4-2	
S_{D1}	0.4022 g ultimate	2/3 0.6033	2/3 S_{M1} design response accelleration at short periods Eq. 9.4.1.2.5-2 / Eq. 11.4-2	

row 60

EQUIVALENT LATERAL FORCE PROCEDURE 9.5.5

ASCE 7-02 and 7-05 callouts are presented as 7-02 / 7-05 for ease of cross-referencing

R	3	unitless	response modification coefficient Tables 9.5.2.2 and 9.14.5.1.1 / Table 12.1-1
Ω_o	3	unitless	system over-strength factor
C_d	2.5	unitless	deflection amplification factor
	4	lookup	Site Classification Table 9.4.1.2 / **?????**
	0	logic	(4 > 5) lookup selection for Site Class Categories A, B, C, D Eqs. 9.5.5.2.1 - 2 & 3
			Site Class A has been removed from ASCE 7-05

$S_{D1\_}$	0.4022 $g_{ultimate}$	IF(0, 0.900 ASCE 9.4.1.3.4, 0.402 ASCE 9.4.1.2.4b)
$S_{DS\_}$	0.7187 $g_{ultimate}$	IF(0, 0.090 ASCE 9.4.1.3.4, 0.719 ASCE 9.4.1.2.4a)

C_s 1	0.2995 $g_{ultimate}$	S_{DS} /(R_ /I) Seismic design coefficient (Eq 9.5.5.2-1) 0.719 /(3.0 /1.25)
C_s 2 max	1.6757 $g_{ultimate}$	S_{D1} /T /(R_ /I) (Eq. 9.5.5.2.1-2) 0.402 /0.100 /(3.00 /1.25)
C_s 3 min	0.0395 $g_{ultimate}$	0.044 * S_{DS} * I (Eq. 9.5.5.2.1-3) 0.044 * 0.719 * 1.25
C_s 4 min	0.0747 $g_{ultimate}$	0.5 * S_1 /(R_ /I) (Eq 9.5.5.2.1-4) for design categories E and F 0.5 * 0.358 /(3.0 /1.25)
Site Class	4 lookup	Table 9.4.1.2 Site Classification
	0.040	IF(4 < 6, 0.040, 0.075 Site Classes E & F)

C_s	**0.299** $g_{ultimate}$	MAX(MIN(0.299, 1.676), 0.040) seismic response coefficient, ultimate strength for V = C_s W Eq. 9.5.5.2-1 / Eq. 12.8-1
	0.214 g_{ASD}	0.299 /1.4 seismic response coefficient, working stress

Values from the '97 UBC are: **0.304 Ultimate** **98.5 %**
0.217 Allowable Stress Design

For errata to the ASCE 7-02, click on:
7-02 Errata
7-02 Symbols
7-02 Updated Snow Diagram
7-02 Updated Snow Diagram
http://www.ice-or.com

For maps
http://eqhazmaps.usgs.gov/html/wus2002.html
http://neic.usgs.gov/neis/states/oregon/

ENGINEERING with the SPREADSHEET

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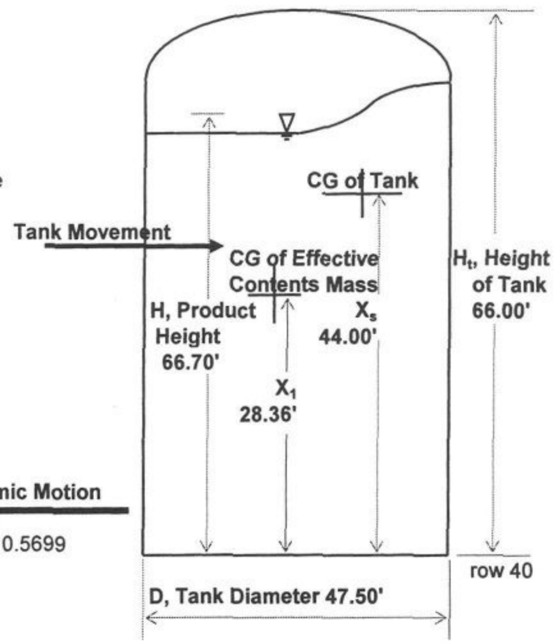
A B C D E F G H I J K L M N

OUTPUT SUMMARY

Wave Action in a Tank Per the AMERICAN PETROLEUM INSTITUTE (API)
Standard 620 Tenth Edition, February 2002

tank_full	**5753**	k	weight of full tank
W_T	5012	k	weight of liquid
$W_{s\ tare}$	**741**	k	weight of empty tank, tare
H	**66.70**	ft	maximum design liquid height
D	**47.50**	ft	tank diameter
G	**0.83**	unit	specific gravity of stored product
density	0.0518	k/ft³	0.83 * 0.0624 density of stored product
circ	149.23	ft	47.50 * π shell circumference
W_{tank}	4.97	k/ft	741 /149.23 tank shell per foot of circumference
V	118196	ft³	π * (47.50 /2)² * 66.70 volume of tank
			118,196 * 7.48052 = 884,168 gallons



row 40

Figure 40-1 Tank elevation and forces.

OVERTURNING MOMENT

Not all of the liquid works to overturn the tank + contents. Much of the potential force is taken out as wave action so that not all of the liquid moves in the same direction of the tank but, instead, much of the liquid moves vertically against the loaded wall.

D/H	0.71	unitless	diameter / height 47.50 /66.70
k_1	0.57		-0.0008 * 0.71³ + 0.0122 * 0.71² - 0.0062 * 0.71+ 0.5699
k	0.59		IF(factor for D/H)
T	4.07	sec	period of first mode sloshing 0.59 * √47.50
S	**1.50**		site amplification factor from API Table L-2
C_{2a}	0.28		0.75 * 1.50 /4.07 for T ≤ 4.5 API L.3.3.2
C_{2b}	0.31		3.375 * 1.50 /4.07² for T > 4.5 API L.3.3.2
C_2	0.28		lateral seismic force coefficient IF(4.07 ≤ 4.5, 0.28, 0.31)
W_1 / W_T	0.84		0.0183 * 0.59² - 0.251 * 0.59 + 0.9798
W_1	**4200**	**k**	weight of the effective mass of the tank contents that moves with the tank, see figure API L-2 0.84 * 5,012 k
W_2 / W_T	0.14		0.001 * 0.71³ - 0.0264 * 0.71² - 0.2481 * 0.71- 0.6 weight of the effective mass of the first mode sloshing of tank contents, see API Figure L-2
W_2	**686**	**k**	weight of effective mass of the first mode sloshing 0.14 * 5,012 k

Site Coefficients	**S**
Rock, shear-wave velocity >2500 fps Stiff or dense soil depth < 200 ft	**1.00**
Stiff or dense soil depth > 200 ft	**1.20**
Soil depth > 70 ft containing 20 ft or more of soft to medium stiff clay but not more than 40 ft of soft clay	**1.50**
More than 40 ft of soft clay where shear-wave < 500 fps	**2.00**

row 50

row 60

row 70

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OVERTURNING MOMENT -- Continued

X_1/H 1	0.43	D/H * -0.07692 + 0.48
		0.71 * -0.07692 + 0.48
X_1/H	0.43	
X_1	**28.36** ft	height to the centroid of lateral seismic force of tank contents that move in unison with the tank, W_1
X_2/H	0.80	0.0005 * D/H^4 - 0.0116 * D/H^3 + 0.0952 * D/H^2 - 0.3437 * D/H + 1
X_2	**53.32** ft	height to the centroid of the tank contents sloshing mass, W_2

Seismic Zone Coefficients

1	**0.075**
2A	**0.15**
2B	**0.2**
3	**0.3**
4	**0.4**

row 80

Importance Factor
Generally the importance factor **I = 1.00**.
Use **I = 1.25** for tanks containing toxic or explosive chemicals.
Many building departments consider cryogenic materials to be hazardous and **I = 1.25**.
The IBC (International Building Code) Table 1604.5 may require **I = 1.50**.

Z	**0.30** unitless	seismic zone coefficient
I	**1.25** unitless	importance factor
W_r	**0** k	total weight of tank roof and insulation, 0 when included in Ws
H_t	**66.00** ft	total height of tank shell
X_s	**44.00** ft	height to the CG of the shell usually taken as 2/3 H_t for flexible structures
C_1	0.6 unitless	arbitrary factor

row 90

Overturning Moment Applied to Bottom of Tank

	19562	$C_1 W_s X_s$ 0.60 * 741 * 44.00
	0	$C_1 W_r H_t$ 0.60 * 0 * 66.00
	71481	$C_1 W_1 X_1$ 0.60 * 4,200 * 28.36
	10115	$C_2 W_2 X_2$ 0.60 * 686 * 53.32
M_{ot}	**37934** k-ft	$Z I (C_1 W_s X_s + C_1 W_r H_t + C_1 W_1 X_1 + C_2 W_2 X_2)$

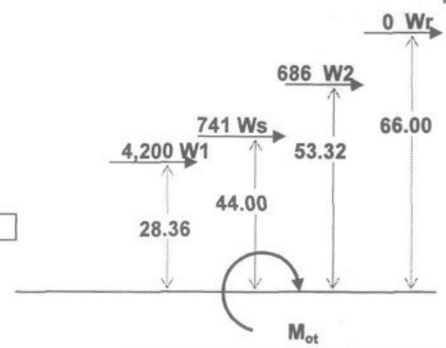


Figure 40-2 Tank overturning forces.

	445 k	$C_1 W_s$ 0.60 * 741
	0	$C_1 W_r$ 0.60 * 0
	2520	$C_1 W_1$ 0.60 * 4,200
	190	$C_2 W_2$ 0.28 * 686
W sum	**1183** k	for lateral forces
W arm	**32.1** ft	37,934 /1,183 vertical arm to lateral forces

row 110

Ratio loads for midline frame
midline 5 columns
total 21 columns
0.238095 ratio

E	**282** k-ft

row 120

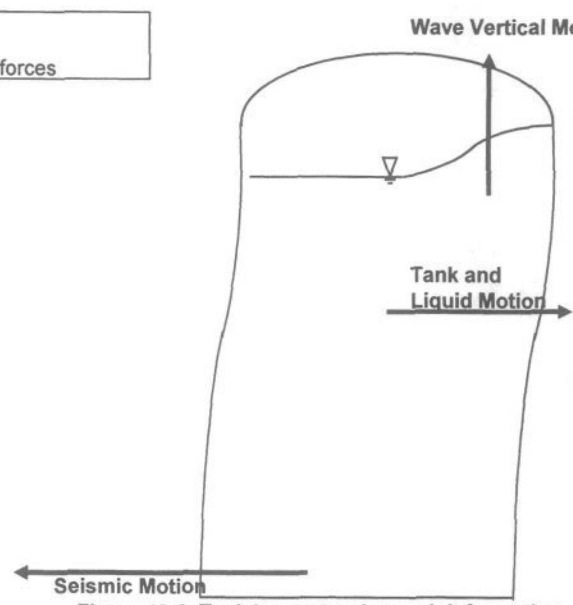
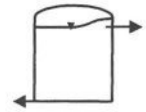


Figure 40-3 Tank in overturning and deformation.

row 130

CELERITY: WAVE ACTION
TANK SUPPORT



A	B	C	D	E	F	G	H	I	J	K	L	M	N

RIGHTING MOMENT

t_b	**0.25**	in	thickness of bottom of tank
t_s	**0.25**	in	shell thickness
F_{by}	**36.0**	k/in^2	minimum yield strength of the bottom shell
W_L 1	9659	lbs/ft	$7.9 * t_b * \sqrt{F_{by} * G * H}$ $7.9 * 0.25 * \sqrt{36.0 * 1000 * 0.83 * 66.70 * 12 \text{ in/ft}}$
$W_{L\ max}$	3287	lbs/ft	$1.25 * G * H * D$ $1.25 * 0.83 * 66.70 * 47.50$
W_L	3287	lbs/ft	weight of contents to resist tank shell overturning
W_{shell}	**4576**	lbs/ft	weight of shell and insulation
W_{rt}	491	k	3,287 * 47.50 PI()/1000 contributing liquid
	683		4,576 * 47.50 * PI()/1000 shell
	0		total weight of tank roof and insulation,
ΣW_{rt}	1173	k	
M_{rt}	**27866**	k-ft	47.50 /2 * 1,173
	0	**logic**	**!!! 27,866 < 37,934 k-ft Mot**

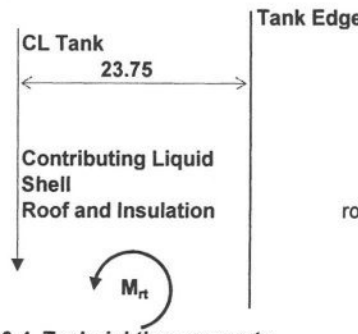


Figure 40-4 Tank righting moments.

row 140

row 150

For Anchored Tank

b	4597	lbs/ft	4,576 + 1.273 * 37,934 /47.50² of shell circumference
σ	1532	lbs/in^2	4,597 /(12 * 0.25) longitudinal stress at bottom of the shell
factor	1998532		0.83 * 66.70 * 47.50² /0.25²
	0	logic	factor > 10^6
F_a	4386	lbs/in^2	10,000,000 * 0.25 /(47.50* 12) shell longitudinal stress
F_a	6219	lbs/in^2	$10{,}000{,}000 * 0.25 /(2.5 * 47.50 * 12) + 600 * \sqrt{0.83 * 66.70}$
F_a	6219	lbs/in^2	IF(0, 4,386, 6,219)
	1	logic	OK 6,219 ≥ 4,386

row 160

row 170

Wave Height

d_{wave}	1.93	ft	$1.124 * Z * I * C_2 * T^2 * \tanh(4.77 * \sqrt{H/D})$ $1.124 * 0.30 * 1.25 * 0.28 * 4.07^2 * \tanh(4.77 * \sqrt{66.70 / 47.50})$

row 180

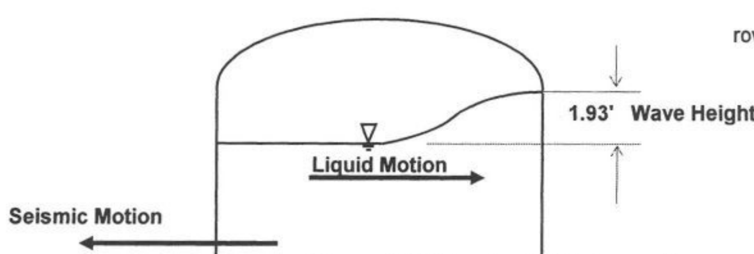


Figure 40-5 Wave height during motion.

row 190

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CELERITY: WAVE ACTION

TANK SUPPORT

ENGINEERING with the SPREADSHEET

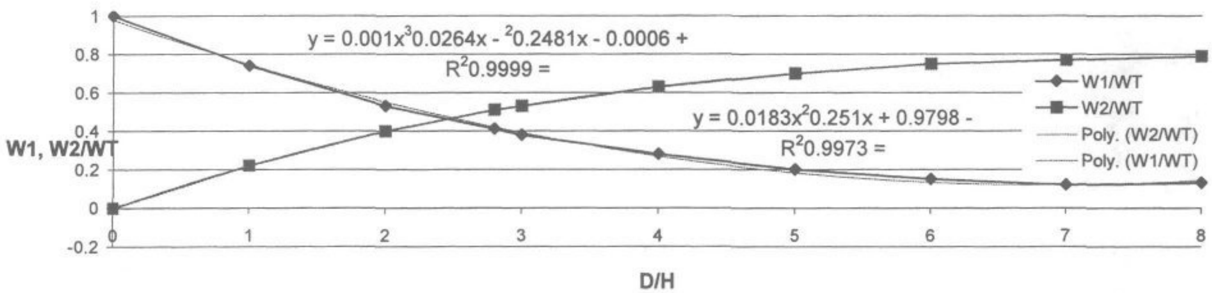
40 Celerity.xls

A B C D E F G H I J K L M N

APPROXIMATIONS of API TABLES

The **Trendline** command with the **Display equation** and **R-squared Values** on chart were used to approximate the API table values so that the chart values can be automaticaly calculated. This does, in fact, reduce errors. The **Trendline** values closely approximate chart values.

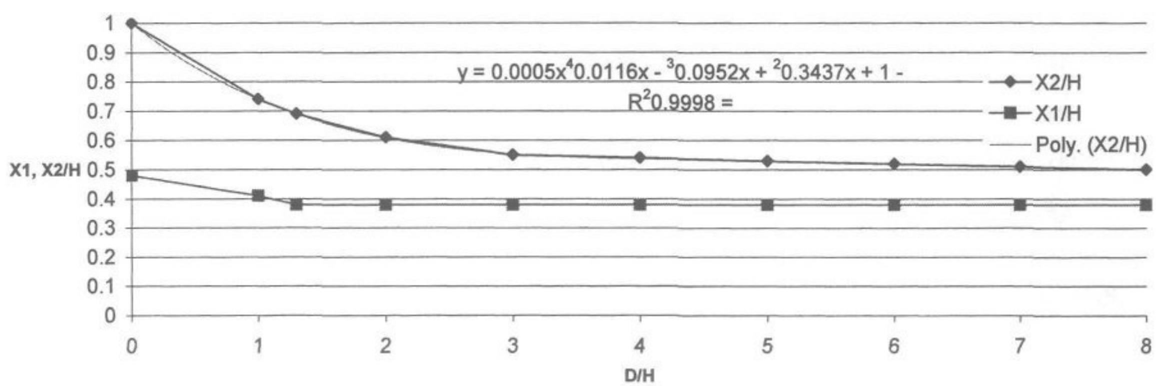
D/H	0	1	2	2.8	3	4	5	6	7	8	
W_1/W_T	1	0.74	0.53	0.41	0.38	0.28	0.2	0.15	0.12	0.13	
W2/WT	0.0	0.22	0.4	0.51	0.53	0.63	0.7	0.75	0.77	0.79	row 200



row 210

Figure 40-6 Diameter/Height versus W1, W2/WT, the effective mass of the first mode sloshing of tank contents API L-2.

D/H	0	1	1.3	2	3	4	5	6	7	8	
X2/H	1	0.74	0.69	0.61	0.55	0.54	0.53	0.52	0.51	0.50	row 220
X1/H	0.48	0.41	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	



row 230

Figure 40-7 Diameter/Height versus X1, X2/H, the height to the centroid of the tank contents sloshing mass, W_2 API L-3.

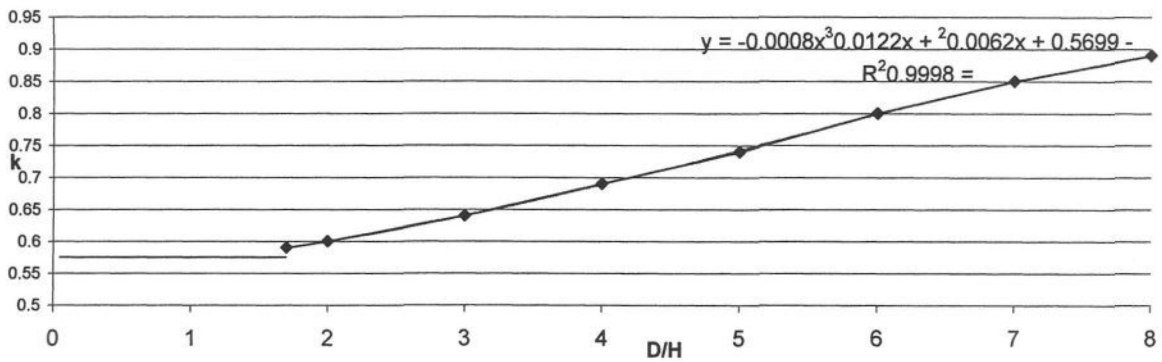
row 240

row 250

A B C D E F G H I J K L M N

APPROXIMATIONS of API TABLES -- Continued

D/H	1.7	2	3	4	5	6	7	8
k	0.59	0.6	0.64	0.69	0.74	0.8	0.85	0.89

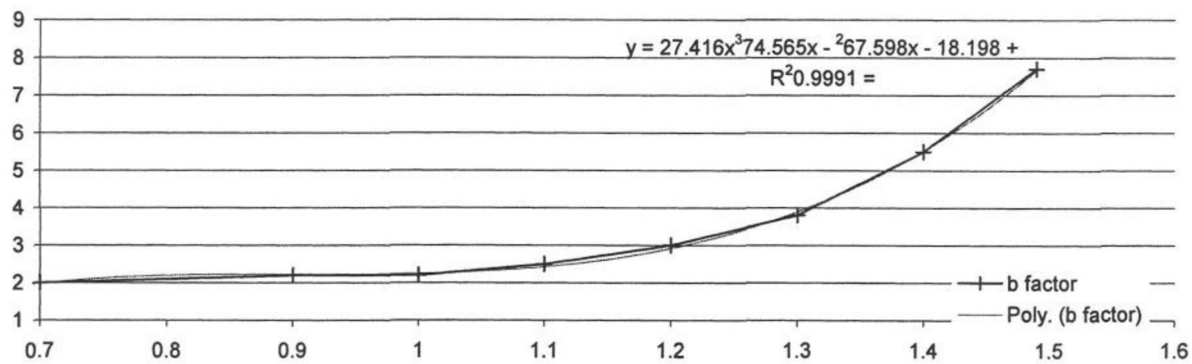


row 260

row 270

Figure 40-8 Diameter/Height versus factor k API L-4.

M_{ot} /(D^2 * (W_l + W_{shell})) *1000	0.7	0.9	1	1.1	1.2	1.3	1.4	1.49
(b + w_L) / (w_t +w_L)	2	2.2	2.2	2.5	3	3.8	5.5	7.7



row 280

row 290

Figure 40-9 Maximum longitudinal compressive force at the bottom of the shell API L-5.

row 300

row 310

CELERITY: WAVE ACTION
TANK SUPPORT

A	B	C	D
Unanchored Tanks for Reference			
limit	2.138		M_{ot} /(D^2 * (W_l + W_{shell})) *1000
			37,934 /(47.50² * (4,576 + 3,287)) * 1000
b	4597	lbs/ft	4,576 + 1.273 * 37,934 /47.50² of shell circumference
σ	1532	lbs/in²	4,597 /(12 * 0.25) longitudinal stress at bottom of the shell
	0	logic	2.138 < 0.785
b	4629	lbs/ft	4,576 + 27.416*limit3 - 74.565 * limit2 + 67.598 * limit - 18.198
	1	logic	2.138 > 0.785
	0	logic	2.138 < 1.5
b	#NUM!	lbs/ft	4,576 + 1.490 / $\sqrt{1 - (0.637 * Mot * 1000 /(D2 * (Wshell + WL))}$
	1	logic	2.138 > 1.5
	0	logic	2.138 < 1.57
b	#NUM!	lbs/ft	
	1	logic	Unanchored tank may be unstable
σ	#NUM!	lbs/in²	#VALUE!

Note: #NUM indicates the square root of a negative number, in this case.

row 320

row 330

row 340

row 350

LOAD RESISTANCE FACTOR DESIGN
TANK SUPPPORT

A	B	C	D	E	F	G	H	I	J	K	L

LRFD FACTORING '97 UBC

1612.2.1 Basic load combinations with exception 2 -- multiply loads with 1.1 for loads including seismic forces

D	**100.0**	dead load -- max DL righting moment	
L	**0**	live load or earth pressure -- max LL righting moment used in seismic	
L_r	**0**	roof live load	
S	**0**	snow	
W	**0**	wind	
E	**0.0**	seismic -- when derived from the UBC, use E/1.4 for working (service level) values	
T	**0**	differential settlement	
H	**0**	earth pressure	row 20
F	**0**	fluid pressure, load factor = 1.4	
max	100.0		
f 1	**1.0**	1.0 floors in public assembly, LL >100 psf, garage 0.5 of other live loads	
f 2	**0.2**	0.7 roofs that can't shed snow, 0.2 other	

97 UBC 1612.2.1

E_	**1.1** multiplier	use 1.1 for concrete and masonry subjected to seismic forces		
12-1	154	1.1 * 1.4 D	← **MOST CONSERVATIVE**	
12-2	132	1.1 * (1.2D + 1.6*L +0.5* (L or S))		row 30
12-3	132	1.1 * (1.2D + 1.6(Lr or S) + (f_1 L or 0.8W))		
12-4	132	1.1 * (1.2D + 1.3W +f_1 L + 0.5(Lr or S))		
12-5a	132	1.1 * (1.2D + 1.0E + (f_1 LL_ + f_2 S))		
			1.32 D + 1.1 E + 1.1 (f_1 L or 0.88 W) + 1.43F	
12-6a	99	1.1 * (0.9D + 1.0E or 1.3W)	0.99 D + 1.1 E or 1.43 W	
12-6b	99	1.1 * (0.9D - 1.0E or 1.3W)	0.99 D - 1.1 E or 1.43 W	
max	154	ratio 1.540		

97 UBC 1909.2 values		Where E is included in the design, use UBC 1612.2.1 per UBC 1909.2.3		
9-1	140	1.4D + 1.7L		row 40
9-2a	105	0.75 (1.4D + 1.7L + 1.7W)	1.05 D + 1.275 L + 1.275 W	
9-3a	90	0.9D + 1.3W		
9-4a	140	1.4D + 1.7L + 1.7H		
9-4b	90	0.9D + 0L + 1.7H		
9-5	105	0.75 (1.4D + 1.4T + 1.7L)	1.05 D + 1.05 L + 1.275 L	
9-6	140	1.4 (D + T)	1.4 D + 1.4 T	
max	140	ratio 1.400		

99 ACI Values		Where E = UBC seismic value / 1.4	
E UBC	0	UBC E / 1.4	row 50
9-1a	140	1.4 D + 1.7 L	
9-1b	140	1.4 D + 1.7 L + 1.4 F	
9-2a	120	1.2 D + 1.6 L + 1.7 W	
9-2b	105	1.05 D + 1.28 L + 1.4 E	
9-3a	90	0.9 D + 1.43 E	
9-3b	90	0.9 D + 1.7 H	
9-4a	140	1.4 D + 1.7 L + 1.7 H	
9-4b	90	0.9 D + 1.7 H	
9-5	105	1.05 D + 1.4 T + 1.275 L	
9-6	140	1.4 D + 1.4 T	row 60
max	140	ratio 1.400	

For lateral force calculations:

E **0.462** **0.30 x 1.4 x 1.1** **structure**

LN2 and tank are calculated separately per API and added to the structure lateral force

row 70

PILE FOUNDATION
TANK SUPPORT

CONSULTING COMPANY

80' Driven Length, 24" Piling

42

Christy
18:20
12/20/05

ENGINEERING with the SPREADSHEET

42 Pile Foundation.xls

A B C D E F G H I J K L M N

SUMMARY for TANK and FOUNDATION

tare	**741**	k	tank
test	**6254**	k	water weight
LN_2	**5012**	k	liquid weight full

test	**6995**	**k**	**tank + weight at test**
Normal	**5753**	**k**	**normal max operating weight**
W contents	**4200**	**k**	**contents that move w/ tank during an event**

diameter	**53**	ft	approximate loaded diameter
area	2206	ft^2	(53 /2)^2 * PI()
q operate	2.61	k/ft^2	Normal /area

row 20

3.5' Elevated Deck

h	**3.5**	ft	
DL	**1839**	k	from AutoCAD massprop calculations
area	3503	ft^2	1,839 /(42 /12 * 0.15)

Piling

Top	1.59	k	24"Φ x 1/2" wall steel casing 0.5 * 24 * PI() /144 * 485 * 12.5 /1000
	5.89	k	concrete top 12.5' 12^2 * PI() /144 * 0.15 * 12.5
	7.48	k	per arbitrary 12.5' trib length of composite pile

row 30

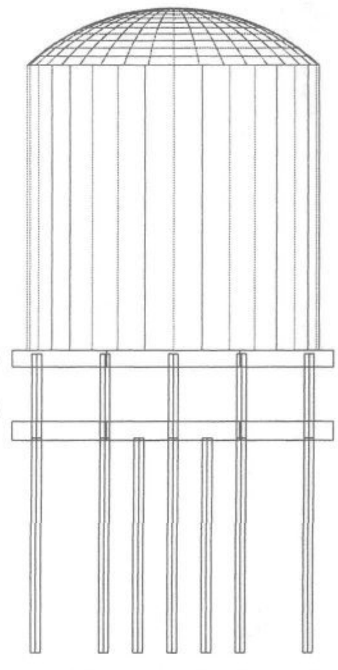


Figure 42-1 Tank and structure elevation.

columns	**21**	each	above the pile cap
	157	k	sum of piling weight above pile cap

row 40

wt steel	485	lb/ft^3
wt conc.	150	lb/ft^3
1 k	1000	lbs

4.0' Pile Cap

h	**4**	ft
DL	**2102**	k

gross opr	5753	k	tank + contents operating weight Liquid
	1839	k	top deck
	157	k	columns
	2102	k	pile cap

row 50

sum	**9851**	**k**	operating load to bottom of pile cap
sum	**11093**	**k**	test load H_2O

A flat bottom 60 foot diameter, 60 foot tall, liquid nitrogen storage tank is supported on a pile foundation at 15' above grade.

Pile foundation and pedestal structure to support:
Tank and contents normal operating weight of 5,753,000 lbs. row 60
Test weight of 6,995,000 Lbs.

Life of the structure is 30 years.

Planar tilt is limited to 1/2" in 60' during the life of the structure. Out-of-plane, differential settlement is limited to 1/8" in 30' and 1/4" in 60' during the life of the structure.'

Settlements will govern this design as much or more than seismic and wind forces.

row 70

PILE FOUNDATION
TANK SUPPORT

80' Driven Length, 24" Piling

A B C D E F G H I J K L M N

DESIGN LOADS for FRAME ANALYSIS PROGRAM

This frame is an elastic ordinary moment resiting frame. The design is for elastic response only and does not use yielding of any member for energy absorbtion. The value of **R** for ordinary moment resisting frames is the same as the **R** for elevated tanks on unbraced legs.

Estimate story shear (V story) to the top of the pile cap

C_a	**0.36**		factor for vertical accelerations
I	**1.25**		importance factor
V	**0.304**	*W	from seismic worksheet
ρ estimate	**1**		estimated redundancy factor
C factor	**1.1**		'97 UBC 1612.2.2.1 Exception 2 for concrete columns

row 80

	DL	seismic shear $_{ult}$	
tank	**741**		
W contents	**5012**		
E tank and contents		**692**	
deck	**1839**	**769**	
col/piles	**157**	**66**	
V story	**7749**	**1527**	**k ult** to top of deck
pile cap	**2102**	**879**	
D	**9851**	**2405**	**k ult** approximate DL + Liquid to top of piling

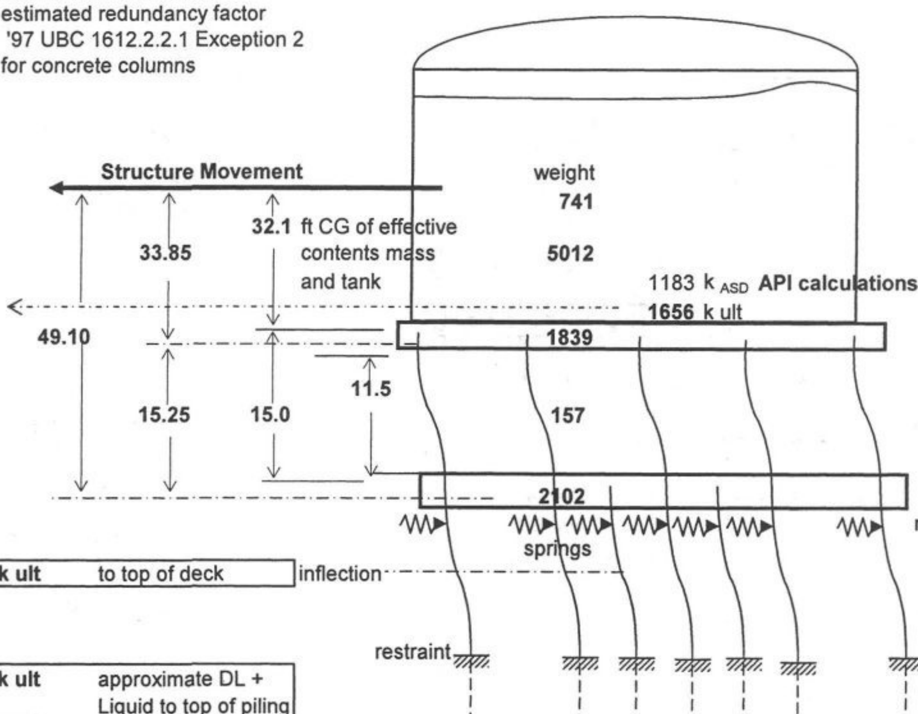


Figure 42-2 Tank and structure with seismic forces.

Check Redundancy

row 110

Overly simplify the model: apply loads to the nodes of the mid-line frame.

Area	**3503**	ft^2	surface area of the deck and/or the pile cap

Redundancy factor for an ordinary moment frame ASCE 7-02 9.5.2.4.2
Item 3 Σ any two adjacent column shears / story shear

column 4	**110**	k ult	from preliminary frame analysis
column 7	**112**	k ult	
sum cols	222		112 + 110
V story	1527	k ult	
r	0.145		222 / 1,527 ratio of any two adjacent column shears to the sum of all column shears

row 120

ρ -0.324 $2 - 20 / (r_{max\,x} \sqrt{A_x})$ $1.0 \le \rho \le 1.5$ max
2 - 20 /[0.145 × 3,503^0.5]

ρ **1** unitless minimum required ρ redundancy factor

row 130

EXTEND PILING THROUGH PILE CAP to DECK

Pile Lateral Resistance

45 piling total

Pile lateral	**90** k →	at 8 diameters through 1" deflection
pile @ 14'	**17** each	
	82 k/each	
	1387 k	
pile @ 7'	**28** each	
	52 k/each	
	1457 k	
pile sum	**2843** k service	pile soil lateral
soil lat	**250** pcf	
face	**78** ft	
depth	**4** ft	
soil p	**156** k	pile cap resistance
pile cap	**2999** k ASD	sum soil and pile lateral resist
V pile cap	2405 k ult	from calculations above
compare	1 logic	
V pile cap	**1718** k ASD	2,405 /1.4 = 1,718 < 2,999 OK

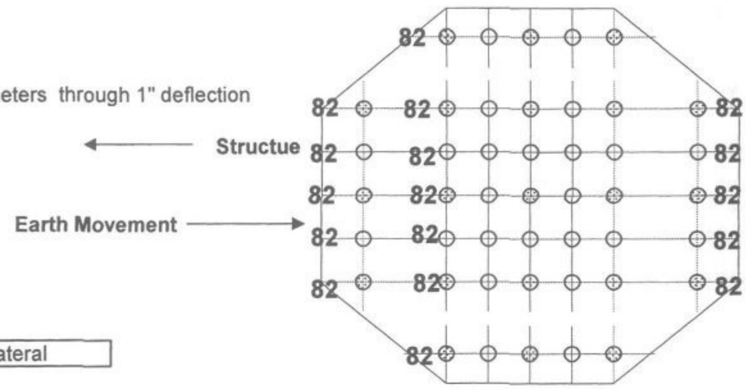


Figure 42-3 This is the piling plan view.

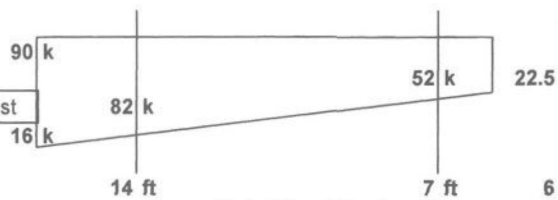


Figure 42-4 Piling lateral resistance -- spacing versus capacity.

row 150

row 160

Piling below the pile cap is considered to be buoyant.

Top of piling fixed within pile cap.

Spring restraint to resemble soil lateral resistance applied at soil/pile cap interface.

Concrete and rebar cage top 25' of pile.

The deck is designed as a two-way slab supported by 21 columns.

For this analysis, S-Frame 3D finite analysis program was used to calculate moments, axial loads, and deflections along the midline of the structure.

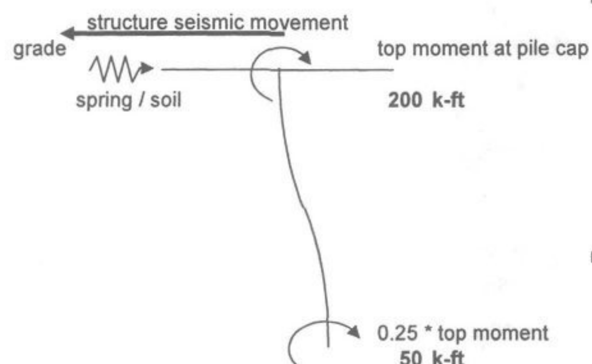


Figure 42-5 Piling applied moments under seismic forces.

row 170

row 180

row 190

LOADS to DECK MID-LINE

Design for the **'97 UBC ultimate strength** of columns. Spring values at grade are given an arbitrary factor of **1.0**.

$E = \rho E_h + E_v = \rho V D + 0.5 C_a I D$ multiply this by **1.1** for concrete '97 UBC 1612.2.2.1 Exception 2

	horizontal component		vertical component
E	1.0 * 1,527 * 1.1	+	0.5 * 0.360 * 1.25 * 9,851 * 1.1
	1679	+	2438

Basic Load Combinations '97 UBC 1612
ratio **0.238** = 5 mid-line columns /21 columns total

D	horizontal component	vertical component
2345 ↓	400 ←	581 ↕

Create load cases for D, E_h, and E_v where: note that D = D + stored liquid

hence:

E_h	0.170 * D	E_h / D
		400 /2,345

and

E_v	0.248 * D	E_v / D
		581 /2,345

Per '97 UBC

(12-1)	1.4 D				
(12-5)	1.2 D	+	1.0 E_h	+	1.0 E_v
(12-6)	0.9 D	±	1.0 E_h	±	1.0 E_v

The load cases are:

1 (12-1)	1.4 D						
2 (12-5)	1.2 D	+	0.170 D horizontal	+	1.0 E per API calc	+	0.248 D vertical
3 (12-6) a	0.9 D	+	0.170 D horizontal	+	1.0 E per API calc	+	0.248 D vertical
4 (12-6) b	0.9 D	+	0.170 D horizontal	+	1.0 E per API calc	-	0.248 D vertical

SUMMARY of LOADS to DECK MID-LINE for FINITE ELEMENT ANALYSIS

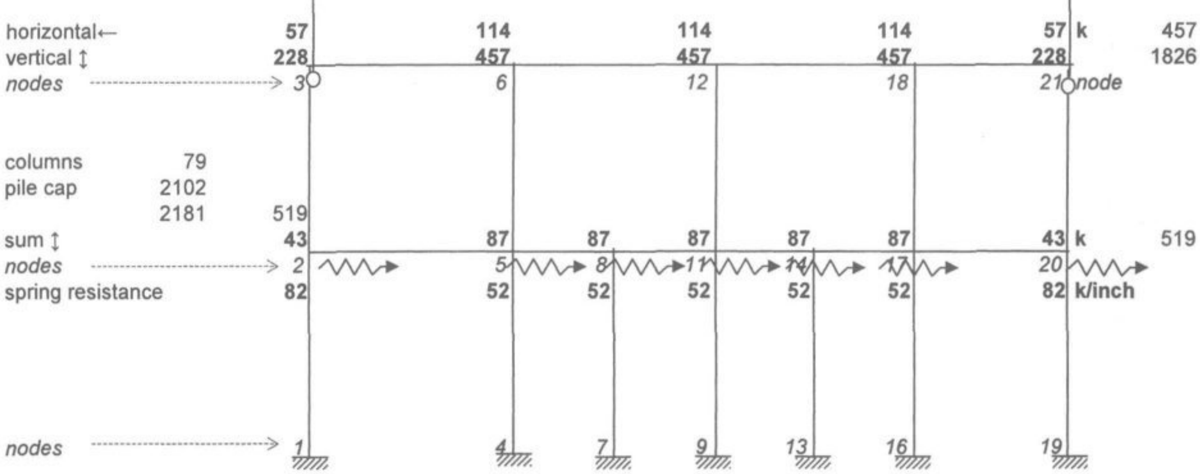
Input D + stored liquid for these nodes:

1,656 * 0.238 ultimate load
394 ← API Calculations

nodes --------------> *22* *node 15 at CG of tank and contents* *23*

	ratio	0.238	
tank + LN_2	5753	1370	for tank + LN_2 as DL only
deck	1839		for vertical loads including tank, LN2, deck, columns
columns	79		
sum	1918	457	1,918 * 0.238 for horizontal loads
sum	7671		457 + 1,370
		1826	7,671 * 0.238 for vertical loads including tank, LN2, deck, and columns

row 260



row 270

row 280

row 290

row 300

row 310

PILE FOUNDATION
TANK SUPPORT

80' Driven Length, 24" Piling

A B C D E F G H I J K L M N

LOADS to DECK MID-LINE by CASE and LOAD COMBINATIONS per '97 UBC

Load combinations are:

1 (12-1) 1.4 D

	C	E	F	G	H	I	K	
1.4 x Case 1 D only	228	457		457		457	228	
node	*3*	*6*		*12*		*18*	*21*	
	43	87	87	87	87	87	43	
node	*2*	*5*	*8*	*11*	*14*	*17*	*20*	row 320

2 (12-5) 1.2 D + 0.170 D horizontal + 0.248 D vertical

	C	E	F	G	H	I	K	
1.448 x Case 1 D	228	457		457		457	228	where: 1.2 + 0.248
0.148 x Case 2 E	57	114		114		114	57	
1.0 x Case 3 E API			394					
node	*3*	*6*	*15*	*12*		*18*	*21*	
1.448 x Case 1 D	43	87	87	87	87	87	43	where: 1.2 + 0.248
0.148 x Case 2 E	43	87	87	87	87	87	43	
node	*2*	*5*	*8*	*11*	*14*	*17*	*20*	

3 (12-6) a 0.9 D + 0.170 D horizontal + 0.248 D vertical

	C	E	F	G	H	I	K	
1.148 x Case 1 D	228	457		457		457	228	where: 0.90 + 0.248
0.148 x Case 2 E	57	114		114		114	57	
1.0 x Case 3 E API			394					
node	*3*	*6*	*15*	*12*		*18*	*21*	
1.448 x Case 1 D	43	87	87	87	87	87	43	where: 0.90 + 0.248
0.148 x Case 2 E	43	87	87	87	87	87	43	
node	*2*	*5*	*8*	*11*	*14*	*17*	*20*	

4 (12-6) b 0.9 D + 0.170 D horizontal — 0.248 D vertical

	C	E	F	G	H	I	K	
0.652 x Case 1 D	228	457		457		457	228	where: 0.90 — 0.248
0.148 x Case 2 E	57	114		114		114	57	
1.0 x Case 3 E API			394					
node	*3*	*6*	*15*	*12*		*18*	*21*	
0.652 x Case 1 D	43	87	87	87	87	87	43	where: 0.90 — 0.248
0.148 x Case 2 E	43	87	87	87	87	87	43	
node	*2*	*5*	*8*	*11*	*14*	*17*	*20*	row 350

Axial and moment forces were generated from a subsequent computer run.
These loads are:

axial	460	k ult
moment	1174	k ult

row 360

row 370

A B C D E F G H I J K L M N

LOADS to DECK MID-LINE USING ASCE 7-02 STRENGTH DESIGN

This frame is an elastic ordinary moment resisting frame.

ρ.	**1.0**	unitless	from above
S_{DS}	**0.719**	g_{ult}	short period spectral response 9.4.1.2.5-1
Cs	**0.299**	g_{ult}	seismic response coefficient 9.5.5
D	**9851**	k	from above
Vert story	1417	k_{ult}	0.2 * 0.719 * 9,851
V story	2945	k_{ult}	0.299 * 9,851

row 380

Basic Load Combinations ASCE 7-02
ratio **0.238** = 5 mid-line columns /21 columns total

D	horizontal component	vertical component	
2345	701	337	← ratioed loads
0.238 * 9,851	0.238 * 2,945	0.238 * 1,417	

row 390

$E_{\rho 1}$ ρQ_E + **0.2 S_{DS} D** Eq. 9.5.2.7 - **1**

Case $5_{2.3.2}$	1.2 D	±	$\rho E_{\rho 1}$	±	0.2 S_{DS} D
	2815 vertical	±	701 horizontal	±	337 vertical
	1.2 * 2,345		1.0 * 701		337

$E_{\rho 2}$ ρQ_E - **0.2 S_{DS} D** Eq. 9.5.2.7 - **2**

Case $8_{2.3.2}$	0.9 D	±	$\rho E_{\rho 2}$	±	0.2 S_{DS} D
	2111 vertical	±	701 horizontal	±	337 vertical
	0.9 * 2,345		1.0 * 701		337

row 400

Create load cases for D, Q_E, and 0.2 S_{DS} D

where:	ρQ_E /D =	701 /2,345 =	0.299 * D
and	0.2 S_{DS} D /D =	337 /2,345 =	0.144 * D

These factors are to be used in the computer finite element analysis "Load Combinations." row 410

The load cases are:

1	D only	1.4 D						
2	$5_{2.3.2}$	1.2 D	+	0.299 D horizontal	+	1.0 E per API calc	+	0.299 D vertical
3	$8_{2.3.2}$a	0.9 D	+	0.299 D horizontal	+	1.0 E per API calc	+	0.144 D vertical
4	$8_{2.3.2}$b	0.9 D	+	0.299 D horizontal	+	1.0 E per API calc	–	0.144 D vertical

row 420

These results are slightly less conservative than the '97 UBC results above

row 430

LOADS to DECK MID-LINE USING ASCE 7-05 STRENGTH DESIGN for Comparison

This frame is an elastic ordinary moment resisting frame.

ρ.	**1.00** unitless	from above
S_{DS}	**0.719** g_{ult}	short period spectral response 9.4.1.2.5-1
Cs	**0.299** g_{ult}	seismic response coefficient 9.5.5
D	**9851** k	from above
Vert story	1417 k_{ult}	0.2 * 0.719 * 9,851 7-05 0.2 SDS D 12.4-4 and 12.14-6
V story	2945 k_{ult}	0.299 * 9,851 7-05 V = Cs W 12.8-1

row 440

Basic Load Combinations ASCE 7-05 Where 12.4.2.3 is used in lieu of 2.3.2

ratio **0.238** = 5 mid-line columns /21 columns total

D	horizontal component	vertical component	
2345	701	337	← ratioed loads
0.238 * 9,851	0.238 * 2,945	0.238 * 1,417	

row 450

Case 5 (1.2 + **0.2** S_{DS}) **D** + ρQE + ~~L~~ + 0.2 ~~S~~

1.2 D	±	ρ $E_{\rho 5}$	±	0.2 S_{DS} D
2815 vertical	±	701 horizontal	±	337 vertical
1.2 * 2,345		1.0 * 701		337

Case 6 (0.9 - **0.2** S_{DS}) **D** + ρQE + 1.6 ~~H~~

0.9 D	±	ρ $E_{\rho 6}$	±	- 0.2 S_{DS} D
2111 vertical	±	701 horizontal	±	337 vertical
0.9 * 2,345		1.0 * 701		337

row 460

Create load cases for D, Q_E, and 0.2 S_{DS} D

where:	ρ Q_E /D =	701 /2,345 =	0.299 * D
and	0.2 S_{DS} D /D =	337 /2,345 =	0.144 * D

These factors are to be used in the computer finite element analysis "Load Combinations." row 470

The load cases are:

1 D only	1.4 D							
2 Case 5	1.2 D	+	0.299 D horizontal	+	1.0 E per API calc	+	0.299 D vertical	
3 Case 6	0.9 D	+	0.299 D horizontal	+	1.0 E per API calc	+	0.144 D vertical	

row 480

row 490

A B C D E F G H I J K L M N

GENERATE ASD ASCE 7-02 LOADS for DEFLECTION CALCULATIONS

ρ **1.0** unitless from above

S_{DS} **0.719** g_{ult} short period spectral response
Cs **0.299** g_{ult} seismic response coefficient

D **9851** k from above

Vert story 1417 k_{ult} 0.2 * 9,851 * 0.719
V story 2945 k_{ult} 9,851 * 0.299 row 500

Basic Load Combinations ASCE 7-02
ratio **0.238** = 5 mid-line columns /21 columns total

D	horizontal component	vertical component
2345	701	337

$E_{\rho 1}$ ρQ_E **+ 0.2** S_{DS} **D** Eq. 9.5.2.7 - **1**

row 510

Case $5_{2.4.1}$	1.0 D	±	0.7 $E_{\rho 1}$	+	0.2 S_{DS} D
	2345 vertical		491 horizontal		337 vertical

$E_{\rho 2}$ ρQ_E **- 0.2** S_{DS} **D** Eq. 9.5.2.7 - **2**

Case $8_{2.4.1}$	0.6 D	±	0.7 $E_{\rho 2}$	-	0.2 S_{DS} D
	1407 vertical	±	491 horizontal	-	337 vertical

row 520

Create load cases for D, Q_E, and 0.2 S_{DS} D

where: $\rho Q_E / D$ = 491 /2,345 = 0.209 * D
and 0.2 S_{DS} D /D = 337 /2,345 = 0.144 * D

Note that the reciprocal of 0.7 is approximately 1.4. This is the standard way to reduce LRFD seismic to ASD levels.

The load cases are: row 530

1	$5_{2.4.1}$	1.0 D	+	0.209 D horizontal	+	0.144 D vertical
2	$8_{2.4.1}$a	0.6 D	+	0.209 D horizontal	+	0.144 D vertical
3	$8_{2.4.1}$b	0.6 D	+	0.209 D horizontal	–	0.144 D vertical

Use these applied strength design (ASD) loads to compute deflections in the computer finite element analysis "Load Combinations."

row 540

GENERATE ASD ASCE 7-05 LOADS for DEFLECTION CALCULATIONS for Comparison

ρ	**1.0** unitless	from above	
S_{DS}	**0.719** g_{ult}	short period spectral response	
Cs	**0.299** g_{ult}	seismic response coefficient	
D	**9851** k	from above	
Q_E	2945 k_{ult}	9,851 * 0.299 where Q_E = V	row 550

Basic Load Combinations ASCE 7-05 Where 12.4.2.3 is used in lieu of 2.4.1
ratio **0.238** = 5 mid-line columns /21 columns total

D	horizontal component
2345	701

Case 5 (1.0 + **0.14** S_{DS}) **D** + H + F + 0.7 ρQ_E

1.0 D	+	0.7 Q_E	+	0.2 S_{DS} D	row 560
2345 vertical		491 horizontal		337 vertical	

Case 6 (1.0 + **0.105** S_{DS}) **D** + ~~H~~ + ~~F~~ + 0.525 ρQE + 0.~~75~~ L + 0.~~75~~ (L_r or S or R)

1.0 D	+	0.525 Q_E	+	0.105 S_{DS} D
2345		368		177

Case 8 (1.0 - **0.14** S_{DS}) **D** + 0.7 ρQ_E + ~~H~~

0.6 D	+	0.7 Q_E	–	0.14 S_{DS} D	row 570
1407 vertical	+	491 horizontal	–	236 vertical	

Note that the reciprocal of 0.7 is approximately 1.4. This is the standard way to reduce LRFD seismic to ASD levels.

The load cases are:

1	Case 5	1.0 D	+	0.209 D horizontal	+	0.144 D vertical	row 580
2	Case 6	0.6 D	+	0.157 D horizontal	+	0.075 D vertical	
3	Case 8	0.6 D	+	0.209 D horizontal	–	0.101 D vertical	

Use these applied strength design (ASD) loads to compute deflections in the computer finite element analysis "Load Combinations."

row 590

row 600

TWO WAY SLAB LOADING
TANK SUPPORT

A B C D E F G H I J K L M N

COLUMN STRIPS

L_1	**14**	ft	
L_2	**14**	ft	
dia	**24.0**	in	circular column
L_n	12.0	ft	

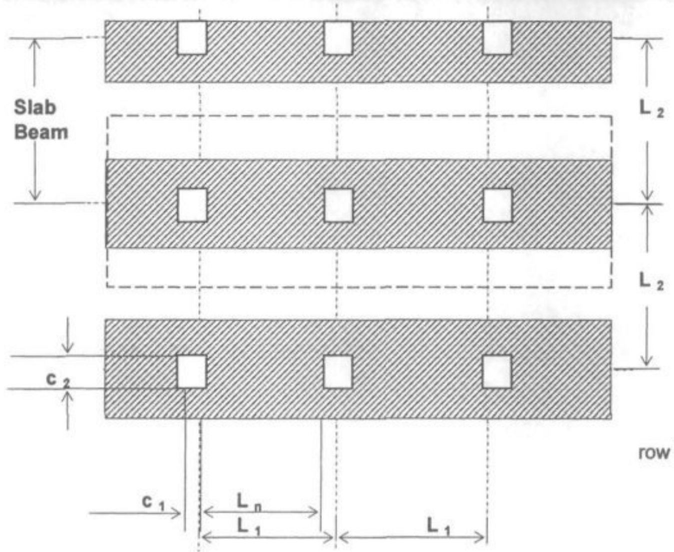


Figure 43-1 FRAMING LAYOUT PLAN

TWO WAY SLAB LOADING

Column strips are set at a 7' x 12'/' = 84" width.
Column strips serve as beams to resist lateral forces.

DL + Fluid + Seismic moments are added to column induced moments

Concrete

Col Strip	**3.5**	ft	
	2.0	ft	
	0.15	k/ft^3	
	1.05	k/ft	Column Beam Strip
Tri Max	**3.5**	ft	
	12.0	ft	
	0.15	k/ft^3	
	6.3	k/ft	mid-point

Load

Col Strip	**2.0**	ft	
	2.61	k/ft^2	
	5.22	k/ft	column strip
Tri Max	**12.0**	ft	
	2.61	k/ft^2	
	31.32	k/ft	mid-point

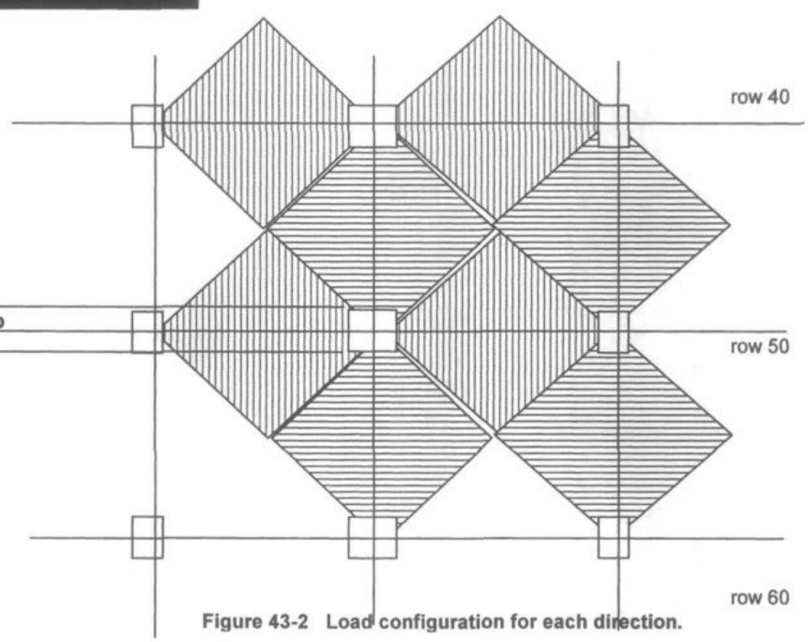


Figure 43-2 Load configuration for each direction.

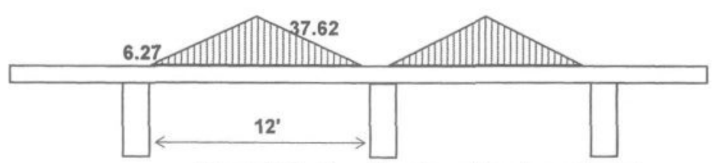


Figure 43-3 Elevation view of loads on the slab.

row 70

ENGINEERING with the SPREADSHEET

A B C D E F G H I J K L M N

FLOW DIAGRAM

YOU MUST HAVE A COPY OF AMERICAN CONCRETE INSTITUTE's ACI 318-MOST RECENT (2002) TO FOLLOW THIS DESIGN PROCESS. http://www.aci-int.org/general/home.asp

This text *refers you to ACI 318 code and commentary. The commentary includes background on code* provisions, clarifying language, and diagrams.

Professional judgement must be exercised when using this example or the template for any application. This is not a reproduction of the ACI 318 code or a shortcut on know-how.

row 20

Please note that much of the text in this printed chapter is not included in the template.

Numbering in ACI 2002 is somewhat different than numbering in ACI 1999. This template follows the ACI 2002 numbering system.

INPUTS

Dimensions and reinforcing

Lengths, k, P_U, and M_U required in x and y directions

COLUMN SUMMARY

Iterate for eccentricity e and compression block C row 30

General values

COLUMN SLENDERNESS and MOMENT MAGNIFIER

M_1	smaller factored end moment
M_2	larger factored end moment
M_{2S}	factored load due to loads causing appreciable sidesway
Q	$\Sigma P_U \Delta_o / (\Sigma V_U L_C) \le 0.05$ then non-sidesway

row 40

MOMENT MAGNIFIER for NON-SWAY FRAMES

C_m	factor for moment magnification for members without transverse loads
	$0.6 + 0.4\ M_1/M_2 \geq 0.4$ ACI 10.12.3.1 (10 -4)
where:	$M_{2,\ minimum} \geq P_u$ k_ult * (0.6 + 0.03h) in where $0.6 + 0.03h = e_{mnimum}$
K L /r	$\le 34 - 12 * M_{U1} / M_{u2} \le 40$ M magnifier not required ACI (10-8)
EI	$(E_C\ I / 5 + 29000\ I_s) / (1 + \beta_d)$ ACI (10-12)
or	$0.4\ E_c I_g / (1 + \beta_d)$ ACI (10 - 13)
P_C	$\pi^2 EI / (k_{braced}\ L)^2$ Euler buckling load ACI 10.12.3 (10-11)
d_{ns}	$C_m / (1 - P_U / (0.75 * P_C)) \geq 1.0$ ACI (10-10)
M_C	$d_{ns} M_2$ end moment for non-sway frame

row 50

Figure 44-1 Flow Diagram row 60

CONCRETE BIAXIAL COLUMN: INTRODUCTION
TANK SUPPORT

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A B C D E F G H I J K L M N

FLOW DIAGRAM -- Continued

MOMENT MAGNIFIER for SIDESWAY FRAMES

Q $\Sigma P_U * \Delta_o / (\Sigma V_U * \ell_c) \leq 0.05$ ACI 10.11.4.2 (10 - 7)

sway $k\,\ell_u / r \leq 22$ non-sway frame ACI 10.13.2

β_d ratio of sustained axial load to maximum axial load for non-sidesway condition ratio of the maximum sustained shear to the maximum shear within a story for sidesway condition — row 70

EI_{minnum} $((E_C\, I\ / 5) + 29000\, I_s) / (1 + \beta_{d\,X})$ ACI (10-12)
or $0.4\, E_c I_g / (1 + \beta_d)$ ACI (10 - 13)

ΣP_C's sum of critical column axial loads

P_C $\pi^2 * EI / (k \text{ unbraced} * \ell_U)^2$ sidesway ACI 10.12.3 (10-11)

$d_s M_s$ $M_s / (1 - Q) \geq M_s$ — row 80

$d_S M_{2S} / M_{2S} \leq 1.5$ ACI 10.13.4.2
$d_s M_s$ $\max(M_s, M_s / (1 - SumP_{U\,X} / (0.75\, SumP_{C\,X})))$

M_1 $M_{1ns} + \delta_s M_{1s}$

M_2 $M_{2ns} + \delta_s M_{2s}$

COLUMN COMBINED LOADINGS for BIAXIAL ANALYSIS — row 90

$e_{required}$ trial value
β_1 concrete strength reduction factor
c_b maximum balanced compression block
a_{max} maximum allowable compression block

REINFORCING AREA and LAYOUT

Tables that organize data for the following calculations — row 100

PLASTIC CENTROID INERTIA CALCULATIONS

CG center of gravity
I_g gross moment of inertia for concrete
PC plastic centroid which yields uniform strain all across column

Figure 44-2 Flow Diagram

row 110

A B C D E F G H I J K L M N

FLOW DIAGRAM -- Continued

PLASTIC CENTROID STRAIN CALCULATIONS

C_TEST	input from C_test in the summary window
ø	tied / spiral columns
STL_COMP	compression compatibility user input, usually 1

row 120

For [Pn]*en

T_S arm	tension reinforcing from the centroid
C_S arm	compression reinforcing from the centroid
C_C arm	compression block concrete
$P_n e_n$	T_S arm + C_S arm + C_C arm
e_n	calculated eccentricity at balanced strain condition

row 130

MATH for <u>RECTANGULAR</u> ROTATING COMPRESSION BLOCK

MATH for <u>SEMICIRCULAR</u> ROTATING COMPRESSION BLOCK

Figure 44-3 Flow Diagram Continued

row 140

row 150

row 160

A B C D E F G H I J K L M N

NOTATIONS

Notations and text are repeated in the text for your convenience.

β — the moment created by the combined, magnified $M_{C2\,x}$ and $M_{C2\,y}$ moments, radians

β_1 — reduction factor for concrete strengths greater than 4000 psi, unitless

β_d — ratio of maximum factored sustained axial load to maximum factored axial load for non-sidesway condition
ratio of the maximum sustained shear to the maximum shear within a story for sidesway condition
β_d is generally 0 for sway deflections due to wind and earthquake
β_d will be greater than 0 for sway conditions resulting from conditions such as a retaining structure

row 170

CG — center of gravity of an area (mass), or a combination of areas.

C_m — a factor adjusting the applied moments to an equivalent applied uniform moment,
0.6 + 0.4 * (M1 / M2) , cannot be less than 0.4
C_m = 1 for transverse loads, unitless ACI 10.12.3.1

C_TEST — the user input for the depth of the compression block, in

d — distance from a point, usually the CG of a mass to the CG of a finite element used in Ad^2, in — row 180

Δo — relative lateral deflection between the top and bottom of a story
due to Vu as calculated by a first-order analysis, in

$\delta_{b\,x}$ — C_m / (1 - $P_{U\,x}$ / (0.75 * $P_{C\,x}$)) magnification factor for a braced frame

$d_{ns\,x}$ — moment magnification factor for braced frame / no sidesway, unitless

$\delta_{s\,x}$ — M_s / (1 - Sum$P_{U\,x}$ / (0.75 * Sum$P_{C\,x}$)) magnification factor for an unbraced (sway) frame

E_C — concrete modulus of elasticity, ksi

row 190

e — eccentricity -- M_n / P_n
e = 0 — vertical axis, P
e ≤ ∞ — horizontal axis, M
Axial and moment loads are converted to
a single load at an eccentricity.

$e_{min\,x}$ ↑ — minimum eccentricity of applied axial load, in

e_n — e_b eccentricity at balanced strain condition, in

row 200

$ø_1$ — strength adjustment factor, unitless
Tied columns = 0.7, Spiral tied columns = 0.75
ACI 9.3.2.2

$I_{g\,xx}$ ↑ — gross moment of inertia including reinforcing, in^4
the ↑ refers to the direction (not the vector) of the value

k — effective height factor, unitless

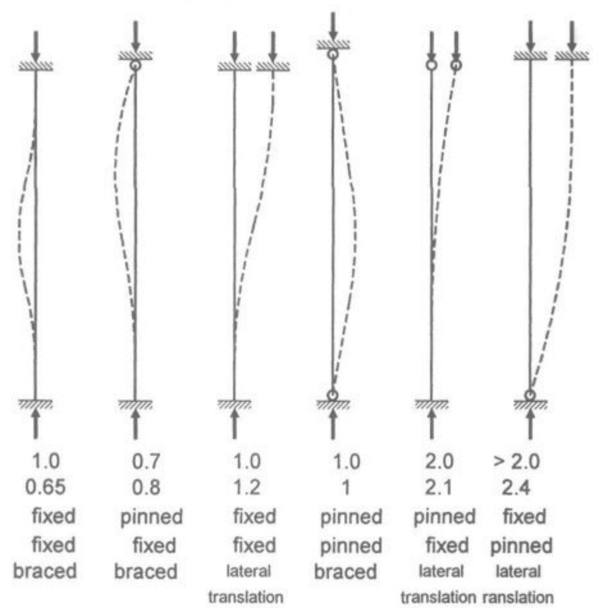

Figure 44-4 Vaules for the effective height factor — row 210

CONCRETE BIAXIAL COLUMN: INTRODUCTION
TANK SUPPORT

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A	B	C	D	E	F	G	H	I	J	K	L	M	N

NOTATIONS -- Continued

L_{xx} horizontal dimention of the column in plan view, in

L_C column length, usually center to center of floor slabs or beams, ft
L is used in lieu of ℓ because ℓ does not appear in range names

L_U unsupported length of column

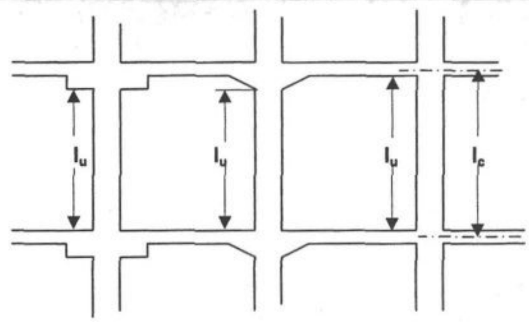

Figure 44-5 Definitions of column unsupported length.

M_1 smaller factored end moment -- postive in single curvature bending, negative in double curvature bending

M_{1ns} factored end moment at end at which the smaller **M_1** moment acts without causing appreciable sidesway row 230
M_{1s} factored end moment at end at which the smaller **M_1** moment acts **causing appreciable sidesway**

M_{2ns} factored end moment at end at which **M_2** acts without causing appreciable sidesway
M_{2s} factored end moment at end at which **M_2** acts **causing appreciable sidesway**

M_{C1} smaller factored moment to be used in column design

M_{C2} larger factored moment to be used in column design

M_b moment at balanced strain conditions row 240
M_c factored moment to be used for the design of a compression member
M_{cr} moment causing flexural cracking
M_n nominal moment strength at a given load eccentricity
M_o nominal moment strength at 0 axial load
M_U factored moment, k-ft ult

P_b nominal axial load strength at balanced strain conditions
P_C π^2 * EI / (k braced * L_U)^2 Euler buckling load ACI (10-10), k
PC plastic centroid which yields uniform strain all across column, in
P_n nominal load strength at a given load eccentricity row 250
P_o nominal axial load strength at 0 eccentricity
P_U LRFD factored applied axial load, k-ultimate

Q stability index for a story ACI 10.11.4.2

ρ A_s / A_{gross} density of reinforcing, unitless

r_x↑ radius of gyration of the column used in the slenderness calculation k L /r, in

W_{yy} vertical dimension of column in plan view row 260

CONCRETE BIAXIAL COLUMN: INTRODUCTION

TANK SUPPORT

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A B C D E F G H I J K L M N

CALCULATIONS

Convergence is used to calculate this template because the template always works as a biaxial column template. You must balance the column's axial capacity and moment capacity against axial and moment demands. The result must fall within the interaction diagram. There is almost never an exact answer.

For $P_U = 0$, use C_Test ≤ a_max and design the column as a beam

Iteration for a tension column is done by hand so that $P_n\ e_n = -P_n\ e$ which occurs at -200% convergence.
Input tension values as positive. These values serve as comparison aids in the summary sheet. row 270

The area of steel must provide the tension resistance.
ø axial tension = 0.90 ACI 9.3.2.1
For TENSION Columns, -Pn > Pu_req and Mup > Mu_req to show
that required capacity is within the capacity envelope.

row 280

row 290

row 300

row 310

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN

TANK SUPPORT

45

Christy

18:23

12/20/05

ENGINEERING with the SPREADSHEET

45 Concrete Column.xls

A	B	C	D	E	F	G	H	I	J	K	L	M	N

CONCRETE CIRCULAR COLUMN DESIGN — Circular, β = 90.00°

L_{input} →	24	in	diameter for circular columns
W_{input} ↑	24	in	Rectangular
Shape	Circular		Circular
	0	logic	

length / diameter 24 in

top

f_Y	60	ksi		
f'_C	4	ksi		
Bar Size#	9			
	1.00	in^2 area of bar		
Bar Qty	16	bars		

area b1,1 1.00	b2,1 1.00	Y top	b3,1 1.00	b4,1 1.00	
column c1→ 8.1	c2→ 12.0		column c3→ 15.9	c4→ 19.2	row 20
row r1 ↑ 21.4	r1 ↑ 22.1		row r1 ↑ 21.4	r1 ↑ 19.2	
b1,2 1.00	b2,2 9.24	Composite	b3,2 0.00	b4,2 1.00	
c1→ 4.8	c2→ 12.000		c3→	c4→ 21.354	
r2 ↑ 19.2	r2 ↑ 20.480		r2 ↑	r2 ↑ 15.875	
b1,3 1.00	b2,3 0.00		b3,3 9.24	b4,3 1.00	
c1→ 2.6	c2→		c3→ 20.48	c4→ 22.1	
r3 ↑ 15.9	r3 ↑		r3 ↑ 12.00	r3 ↑ 12.0	
X left				X right	
b1,4 1.00	b2,4 9.24		b3,4 0.00	b4,4 1.00	
c1→ 1.9	c2→ 3.52		c3→	c4→ 21.354	
r4 ↑ 12.0	r4 ↑ 12.0		r4 ↑ 0.00	r4 ↑ 8.125	
b1,5 1.00	b2,5 0.00		b3,5 9.24	b4,5 1.00	
c1→ 2.6	c2→		c3→ 12.00	c4→ 19.2	
r5 ↑ 8.1	r5 ↑		r5 ↑ 3.52	r5 ↑ 4.8	
b1,6 1.00	b2,6 1.00		b3,6 1.00	b4,6 1.00	
col c1→ 4.8	c2→ 8.1		column 3→ 12.0	c4→ 15.9	
row r6 ↑ 4.8	r6 ↑ 2.6	Y bottom	row r6 ↑ 1.9	r6 ↑ 2.6	

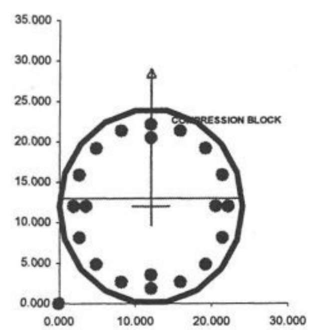


Figure 45-1 Direction of loads and reinforcing placement.

Figure 45-2 Input reinforcing and check for placement.

Tied	0	0 = spiral, 1 = tied	
Tie Size#	3		Input rebar areas and check distances for placement.
	0.11	in^2 area of tie	
Cover	1.50	in	clear distance of rebar from face of column
			See ACI 7.7 clearances, ACI 7.10.4 spirals, ACI 7.10.5 ties, ACI 10.9.3 ρ_{spiral}
symetrical	yes		yes = symmetrical in both directions, no = not symmetrical

White space is left for your input diagrams/drawings.

Reinforcing Lookup Table

Bar Size#	Area
10M	0.16
15M	0.31
20M	0.46
25M	0.77
30M	1.09
35M	1.55
45M	2.32
55M	3.87
0	0
3	0.11
4	0.20
5	0.31
6	0.44
7	0.60
8	0.79
9	1.00
10	1.27
11	1.56
14	2.25
18	4.00

row 70

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN

TANK SUPPORT

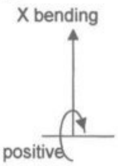
A B C D E F G H I J K L M N

XX COLUMN LENGTHS and LOADS for BENDING ABOUT the X-AXIS — Circular. β = 90.00°

L_x	**14**	ft	center-to-center beam-column joints
k_x	**1.0**	unitless	
L_{ux}	**13.25**	ft	unsupported length of column

FACTORED LOADS

P_u	**465**	k ult	factored axial load
M_{2ux}	**1176**	k-ft ult	factored largest moment, always positive

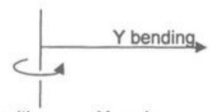


YY COLUMN LENGTHS and LOADS for BENDING ABOUT the Y-AXIS

L_y	**14**	ft	center-to-center beam-column joints
k_y	**1.0**	unitless	
L_{uy}	**13.25**	ft	unsupported length of column

FACTORED LOADS

M_{2uy}	**0**	k-ft ult	factored largest moment, always positive



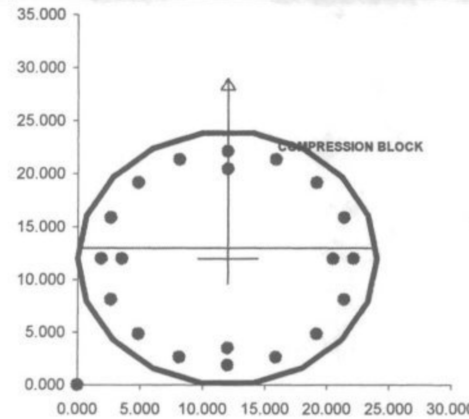


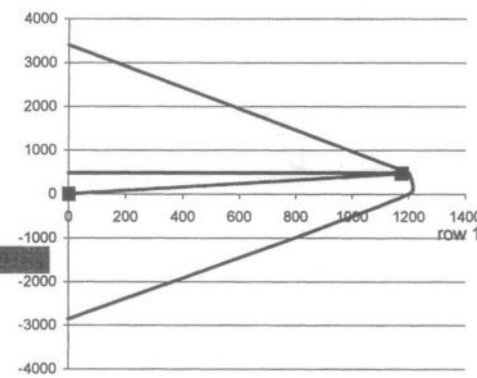
Figure 45-3 Direction of loads with reinforcing location and compression block.

row 80

row 90

BIAXIAL COLUMN SUMMARY

$P_{U\ required}$	465	k-ult	required axial load
P_o	4536	k	nominal axial load at e = 0
P_n	641	k	P_n provided
$ø_3P_{n\ provide}$	481	k-ult	OK ø3Pn provided > 465 k-ult required
$M_{U\ applied}$	1176	k-ft ult	combined applied moments
$M_{C\ required}$	1176	k-ft ult	magnified moments
$M_{U\ provided}$	1202	k-ft	OK Mu provided > 1,176 k-ult Mc required
e_n	29.99	in	
C_Test	**11.000**	in	input value to determine compression block "a"
max diag	24.00	in	
	0		OK k Lu/r 19 ≤ 100 see ACI 10.10.5 braced frame and ACI 10.11.1
	0		OK k Lu/r 19 ≤ 34 - 12 * M1/M2 no moment magnifier ACI 10.12.2
ρ	0.0919	unitless	A_s / A_{gross} density of reinforcing
logic	1		OK 0.0100 ρ minimum ≤ 0.0919 ρ provided ACI 10.9.1
logic	0		!!! 0.0919 ρ provided ≥ 0.0800 ρ maximum ACI 10.9.1



row 100

Figure 45-4 Axial and moment capacities in the interaction diagram.

As M_u changes, $M_{u\ provided}$ will change as a function of e_n * P_u.

row 110

OK k Lu/rx 18.9 ≤ 100 see ACI 10.10.1 braced frame ACI 10.11.5
OK 18.9 ≤ 40.0 no moment magnifier in the X direction
non-sidesway in the X direction ACI 10.22.4.2

OK 18.9 k L/ry ≤ 100 ACI 10.11.5
OK 18.9 ≤ 34.0 no moment magnifier in the Y direction
non-sidesway in the Y direction ACI 10.11.4.2

β	1.571	radians	resulting beta from combined, magnified $M_{C2\ x}$ and $M_{C2\ y}$
	0		ATAN(1,176 / 0)
	90.0000	degrees	rotation of neutral axis counter clockwise from x-axis
$I_{g\ xx}$ ↑	16286	in^4	gross concrete
I_{xx} ↑	18435	in^4	includes ± A_S
$I_{g\ yy}$ →	16286	in^4	gross concrete
I_{yy} →	18435	in^4	includes ± A_S
E_c	3605	ksi	$57000 * \sqrt{f'_c}$
			57000 * 4,000^0.5 / 1000

row 118

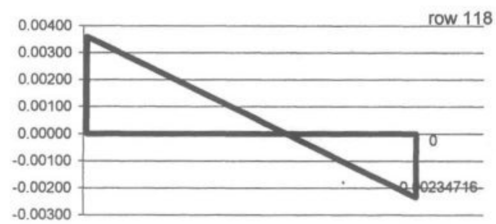


Figure 45-5 Strain profile.

row 130

CONCRETE BIAXIAL COLUMN:
COMPOSITE CIRCULAR COLUMN
TANK SUPPORT

A B C D E F G H I J K L M N

COLUMN SLENDERNESS and MOMENT MAGNIFIER for the X-AXIS Non-Sway Circular. β = 90.00°

length 24 in referenced from above

L_x 14 ft

k_x 1.0 unitless

P_u 465 k ult

E_c 3605 ksi

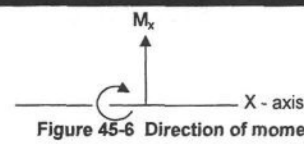


Figure 45-6 Direction of moment icon.

Move the formulas and explanations and copy-clip and park your math in a convenient cell.

$M_{1\,x}$ **-838** k-ft ult

smaller factored end moment, + in single curvature bending (, - in double curvature bending (

$M_{2\,x}$ 1176 k-ft ult larger factored end moment, always positive, referenced from above — row 140

M1 < M2 OK

C_m 0.400 unitless 0.6 + 0.4 * (M_1 / M_2) , cannot be less than 0.4

C_m = 1 for transverse loads ACI 10.12.3.1

$C_{m\,x}$ **0.400** unitless for transverse loading condition

C_m applies to both the minimum e_min P_U moment and the M_{C2} moments.

0 logic Circular

r_x 7.2 in 0.3 * h rectangular column ACI 10.11.2

0.3 * 24.00 in

r_x 6.0 in 0.25 * diameter for circular columns

r_x↑ **8.4** in computed r_y or input r_y as for composite column or

FOR STEEL COLUMN other section ACI (10 - 21) where the ACI quick calculation in ACI 10.11.2 is overly conservative

Note: Greek, italic and math symbols from chapter 6 are used as much as possible to avoid format errors in Greek C, Symbol SH, and Symbol when things are moved around. Super and subscripting must still be redone -- but those errors are more obvious.

Note Also: Symbols from chapter 6 appear as range names when Insert, Name, Define is used. Use L instead of ℓ because ℓ does not show up as a range name.

k L_{ux} /r_x 18.9 unitless k_x * L_{Ux} / r_x

1.0 * 13.25 ft / 8.4 in * 12 in/ft

0 logic

OK k Lu/rx 18.9 ≤ 100 see ACI 10.10.1 braced frame ACI 10.11.5

Subscript Lux rather than LUX which would be the more traditional choice. This is because range naming does not recognize formatted characters. A subscripted Lux which looks like L_{ux} *is more recognizable as a range name.*

Non-sidesway frames may neglect moment magnifier if:

Limit_x 40.0 unitless 34 - 12 * Mu 1 / Mu 2 < 40 ACI 10.12.2 (10-7)

*min(40, 34 - 12 * -838 / 1,176)*

0 logic

OK 18.9 ≤ 40.0 no moment magnifier in the X direction

EI_{xx} 11804527 k-in^2 ((E_C * Ig / 5) + 29000 * I_s) / (1 + $\beta_{d\,x}$) ACI 10.12.3 (10-11)

((3,605 ksi * 16,286 in^4 / 5) + 29 ksi * 2,149.0 in^4) / (1 + 0.00)

EI 23484413 k-in^2 0.4 * E_c * I_g /(1 + b_d) ACI 10.12.3 (10 - 12)

0.4 * 3,605 ksi * 16,286 /(1 + 0.00)

EI min x 11804527 k-in^2 min(23,484,413, 11,804,527) — row 170

$P_{C\,x}$ 4128 k π^2 * EI / (k_x braced * Lu_x)^2 Euler buckling load ACI 10.12.3 (10-10)

9.870 * 3,605 * 16,286 k-in² / (1.00 * 14.00 ft * 12 in/ft)²

$\delta_{ns\,xx}$ 0.471 C_m / (1 - P_u / (0.75 * $P_{c\,x}$)) ACI 10.12.3 (10-9)

0.40 / [1 - 465 / (0.75 * 4,128)]

P_c, the column critical axial load, is ratioed against P_u. This is used to reduce the stiffness factor EI which is important when column axial load is high.

$\delta_{ns\,x}$ 1.000 unitless max(1.0, $d_{ns\,xx}$ * Limit_x logic)

max(1, 0.471 * 0)

M magnification factor for braced frame / no sidesway

row 180

$e_{min\,x}$↑ 1.32 in 0.6 + 0.03 * h minimum allowable e ACI 10.12.3.2 (10-14)

0.6 in + 0.03 * 24.00 in

e_{min} P_u 51.15 k-ult $d_{ns\,x}$ * $e_{min\,x}$ * P_u / 12 in/ft minimum required

1.000 * 1.32 * 465 /12

δ_{ns} M_{c2x} 1176 k-ft ult d_{ns} M_{2x} required

1.000 * 1,176

The d_{ns} moment magnifier applies to both e_min * P_u moment and applied M_{c2} moment. The greater moment governs.

1176 k-ft ult

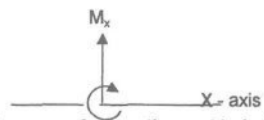
row 190

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN
TANK SUPPORT

A B C D E F G H I J K L M N

COLUMN SLENDERNESS and MOMENT MAGNIFIER for the X-AXIS -- SIDESWAY Circular, β = 90.00°

$\Sigma P_{u\,x}$ **7749** k ult sum of factored axial loads for all columns resisting sidesway
$\Sigma V_{u\,x}$ **1527** k sum of story horizontal shear
M_{2sx} **1174** k-ft ult larger factored moment due to loads causing appreciable sidesway
0 !!! input the larger factored end moment



Icons are frequently used to help the designer and reviewer identify where they are in the calculations.

$D_{o\,x}$ **0.8** in relative lateral deflection

row 200

A story can be considered as non-sidesway if:
Q_x 0.024165 unitless $\Sigma P_{U\,x} * \Delta_o / (\Sigma V_{U\,x} * L_C) \le 0.05$ ACI 10.11.4.2 (10 - 6)
7,749 * 0.80 / (1,527.00 * 14.00 in * 12)
1 logic $Q \le 0.05$ is nonsway in the X direction
non-sidesway in the X direction ACI 10.22.4.2

Member slenderness in a frame not braced against sidesway can be neglected if:
sway x 1 logic $k\, L_U / r \le 22$ ACI 10.13.2
neglect column slenderness k Lu/r = 18.9

row 210

$\beta_{d\,x}$ **0.00** unitless ratio of maximum factored sustained axial load to maximum factored axial load for non-sidesway condition
ratio of the maximum sustained shear to the maximum shear within a story for sidesway condition

Note: If the column is braced against sidesway or meets the conditions of ACI 10.11.4.2 (10-6) story sidesway, use the non-sidesway moment magnifier.

row 220

P_{cx} **4128** k referenced from above
columns **5** each number of columns resisting sway

ΣP_{cx} **20640** k ult sum of P_C's for columns in a story resisting sidesway, for d_s sidesway calculation

row 230

$\delta_s M_{2s\,x}$ 1203 k-ft ult $M_{2S} / (1 - Q)$ ACI 12.13.4.2 (10-17)
1,174 /(1 - 0.02417)

ratio 1.023 unitless $d_S\, M_{2S} / M_{2S}$
1,203 /1,176
0 logic 1.023 ≤ 1.5 ACI 10.13.4.2

The sum of column P_C's is ratioed against the sum of column P_U's in sidesway calculations to reflect the interaction of all sway resisting columns in a story.

$\delta_s M_{2s\,x}$ 2351 unitless $\max(M_S, M_S / (1 - \Sigma P_{U\,x} / (0.75 * \Sigma P_{C\,x})))$ ACI 10.13.4.3 (10-18)
max(1,174, 1,174 /(1 - 7,749 /(0.75 * 20,640 + 0.001)))
M magnification factor for unbraced frame subject to sidesway

$\delta_s M_{2s\,x}$ 1203 k-ft ult IF(0, 2,351, 1,203)

non-sidesway in the X direction ACI 10.22.4.2
$M_{c2\,x}$ 1176 k-ft ult $d_{ns} M_{2x} + d_s M_{2Sx}$
0 + 1,176

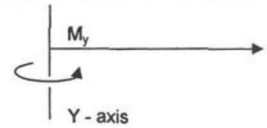
row 250

CONCRETE BIAXIAL COLUMN:
COMPOSITE CIRCULAR COLUMN
TANK SUPPORT

A B C D E F G H I J K L M N

COLUMN SLENDERNESS AND MOMENT MAGNIFIER for the Y-AXIS Non-Sway Circular. β = 90.00°

width 24.0 in referenced from above
L_y 14 ft
k_y 1.00 unitless
P_u 465 k ult
E_c 3605 ksi



$M_{1\,y}$ 0 k-ft ult smaller factored end moment, + in single curvature bending (, - in double curvature bending (
$M_{2\,y}$ 0 k-ft ult larger factored end moment, always positive
M1 < M2 OK
row 260

C_m 0.600 unitless $0.6 + 0.4 * (M_1 / M_2)$, cannot be less than 0.4
$C_m = 1$ for transverse loads ACI 10.12.3.1
$C_{m\,y}$ 1.00 unitless for transverse loading condition

0 logic Circular
$r_y \rightarrow$ 7.2 in *0.3 * h rectangular column ACI 10.11.2*
0.3 * 24.0 in
r_y 6.0 in 0.25 * diameter for circular columns
row 230
r_y 8.4 in computed r_y or input r_y as for composite column or
FOR STEEL COLUMN other section ACI (10 - 21) where the ACI quick
calculation in 10.11.2 is overly conservative

$k\,L_{uy} / r_y$ 18.9 unitless $k_y * L_{U\,y} / r_y * 12$
1.00 * 13.25 ft / 8.4 in * 12 in/ft
0 logic
OK 18.9 k L/ry ≤ 100 ACI 10.11.5

Non-sidesway frames may neglect moment magnifier if:
row 280
Limit_y 34.0 unitless 34 - 12 * Mu 1 / Mu 2 < 40 ACI 10.12.2 (10-7)
min(40, 34 - 12 * 0 / 0)
0 logic
OK 18.9 ≤ 34.0 no moment magnifier in the Y direction

EI_{yy} 11804527 k-in^2 $((E_C * Ig / 5) + 29000 * I_s) / (1 + B_{d\,y})$ ACI 10.12.3 (10-11)
((3,604.997 ksi * 16,286 in^4 / 5) + 29 ksi * 2,149.0 in^4) / (1 + 0.00)
EI 23484413 k-in^2 $0.4 * E_c * I_g /(1 + b_d)$ ACI (10 - 12)
0.4 * 3,605 ksi * 16,286 /(1 + 0.00)
$EI_{min\,y}$ 11804527 k-in^2 min(23,484,413, 11,804,527)
row 290

$P_{c\,y}$ 4128 k $\pi^2 * EI / (k\ braced * L_U)^2$ Euler buckling load ACI (10-10)
9.870 * 3,605 * 16,286 k-in² / (1.00 * 14.00 ft * 12 in/ft)²

$\delta_{ns\,yy}$ 1.177 *$C_m / (1 - P_U / (0.75 * P_{C\,y}))$ ACI 10.12.3 (10-9)*
1.00 / [1 - 465 / (0.75 * 4,128)]
$\delta_{ns\,y}$ 1.000 unitless max(1.0, $d_{ns\,xx}$ * Limit_x logic)
max(1, 1.177 * 0)
M magnification factor for braced frame / no sidesway

P_C, the column critical axial load, is ratioed against P_U . This is used to reduce the stiffness factor EI which is important when column axial load is high.

row 300
$e_{min\,y} \rightarrow$ 1.32 in 0.6 + 0.03 * h minimum allowable e ACI 10.12.3.2 (10-14)
0.6 in + 0.03 * 24.0 in

$e_y \rightarrow$ eccentricity **distance** of load from the centroid of the gross section contributing to M_Y moment, inches

$e_{min}\,P_u$ 51.15 k-ult $d_{ns\,y} * e_{min\,y} \cdot P_U$ / 12 in/ft
1.000 * 1.32 * 465 /12

$\delta_{ns} M_{c2y}$ 0 k-ft ult $d_{ns}\,M_{2x}$ required
1.000 * 0
51 k-ft ult

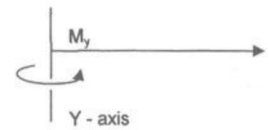
The d_{ns} moment magnifier applies to both the minimum e_min * P_U moment and applied M_{C2} moment. The greater moment governs.

row 310

A B C D E F G H I J K L M N

COLUMN SLENDERNESS and MOMENT MAGNIFIER for the Y-AXIS -- SIDESWAY Circular, β = 90.00°

$\Sigma P_{u\,y}$ 0 k ult for d_{ns} no sidesway calculation, sum of P_U for all column loads in a story
$\Sigma V_{u\,y}$ 0 k
$M_{2s\,y}$ 0 k-ft ult factored load due to loads causing appreciable sidesway
logic 1 .larger factored end moment



D_{oy} 0 in

row 320

A story can be considered as non-sidesway if:
Q_y 0 unitless $\Sigma P_{U\,y} * \Delta_o / (\Sigma V_{U\,y} * L_C) \le 0.05$ ACI 10.11.4.2 (10 - 6)
0.00 k * 0.00 in / (0.00 k * 13.25 in *12)
1 logic $Q \le 0.05$ is nonsway in the Y direction
non-sidesway in the Y direction ACI 10.11.4.2

Member slenderness in a frame not braced againts sidesway can be neglected if:
sway y 1 logic $k\ L_u / r \le 22$
neglect column slenderness k Lu/r = 18.9 row 330

$\beta_{d\,y}$ **0.00** unitless ratio of maximum factored sustained axial load to maximum factored axial load for non-sidesway condition
ratio of the maximum sustained shear to the maximum shear within a story for sidesway condition

row 340

P_{cy} **4128** k referenced from above
columns **0** each number of columns resisting sway

ΣP_{cy} 0 k ult sum of P_c's for columns in a story resisting sidesway, for d_s sidesway calculation

row 350

$\delta_s M_{2s\,y}$ 0 unitless $M_{2S} / (1 - Q)$ ACI 12,13,4,2 (10-17)
0 /(1 - 0.00000)

Σ, sigma this means sum or the sum of
for you liberal arts majors

ratio 0.000 unitless 0 /0
0 logic 0.000 ≤ 1.5 ACI 10.13.4.2

The sum of column P_c's is ratioed against the sum of column P_u's in sidesway calculations to reflect the interaction of all sway resisting columns in a story.

$\delta_s M_{2s\,y}$ 0 k-ft ult $\max(M_S, M_S / (1 - \Sigma P_{U\,x} / (0.75 * \Sigma P_{C\,x})))$ ACI 10.13.4.3 (10-18)
max(0, 0 /(1 - 0 /(0.75 * 0 + 0.001))) row 360
M magnification factor for unbraced frame subject to sidesway

$\delta_s M_{2s\,y}$ 0 k-ft ult IF(0, 0, 0)

non-sidesway in the Y direction ACI 10.11.4.2
$M_{c2\,y}$ 51 k-ft ult $d_{ns} M_{2y} + d_s M_{2Sy}$
0 + 51

row 370

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN

TANK SUPPORT

A	B	C	D	E	F	G	H	I	J	K	L	M	N

MOMENT MAGNIFIER LOGIC SIEVE — Circular, β = 90.00°

	X	Y
$e_{min} P_u$	51.15	51.15
$\delta_{ns} M_{c2}$	1176	0
	1176	51
logic	1	0
$M_{c\ req'd}$	1176	0

e_{min} P_U is applied to only one axis at a time.
I have interpreted the provisions in ACI 10.12.3.2 to mean that if there is *no moment applied in the X or Y axis, e_{min} P_U will not be considered in* that unloaded axis.

Where there is no applied moment, the largest e_{min} P_U will be used in the moment magnifier calculations.

row 380

$M_{c\ req'd}$ 1176 k-ft ult $\sqrt{1{,}176^2 + 0^2}$

COLUMN COMBINED LOADINGS for BIAXIAL ANALYSIS

$M_{u\ applied}$	1176	k-ft ult	$\sqrt{1{,}176^2 + 0^2}$ applied
ΣM_1	838	k-ft ult	$\sqrt{-838^2 + 0^2}$
ΣM_2	1176	k-ft ult	$\sqrt{1{,}176^2 + 0^2}$ braced-frame
ΣM_{2s}	1174	k-ft ult	$\sqrt{1{,}174^2 + 0^2}$ sway-frame
M_c	1176	k-ft ult	$\sqrt{M_{C\,x}^2 + M_{C\,y}^2}$ $\sqrt{1{,}176^2 + 0^2)}$
E_c	3605	k/in^2	*$57000 * f'_c{}^2$* 57000 * 126.49 / 1000000
n	8.04	unitless	$E_{steel} / E_{concrete}$ 29000 ksi / 3,605 ksi
	0.85	*unitless*	*reduce the .85 factor by .05 for each 1000 psi* over 4000 psi
β_1	0.85	unitless	but not less than 0.65 ACI 10.2.7.3

row 390

row 400

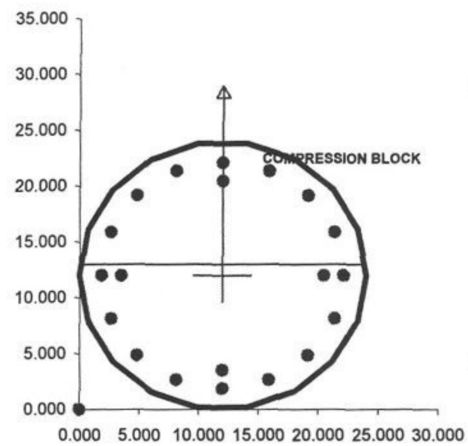


Figure 45-7 Load direction with reinforcing location and compression block.

RENIFORCING AREA and LAYOUT

Reinforcing Nomenclature

				Column			
b1,1	b2,1	b3,1	b4,1	8.125	12.000	15.875	19.158 in
b1,2	b2,2	b3,2	b4,2	4.842	12.000	12.000	21.354
b1,3	b2,3	b3,3	b4,3	2.646	-10.587	20.480	22.125
b1,4	b2,4	b3,4	b4,4	1.875	3.520	6.000	21.354
b1,5	b2,5	b3,5	b4,5	2.646	12.000	12.000	19.158
b1,6	b2,6	b3,6	b4,6	4.842	8.125	12.000	15.875

row 410

Row				Area steel	c1	c2	c3	c4
21.354	22.125	21.354	19.158 in	A r1 c1	1.00	1.00	1.00	1.00 in^2
19.158	20.480	-3.520	15.875	r2	1.00	9.24	0.00	1.00
15.875	5.092	12.000	12.000	r3	1.00	0.00	9.24	1.00
12.000	12.000	0.000	8.125	r4	1.00	9.24	0.00	1.00
8.125	17.625	3.520	4.842	r5	1.00	0.00	9.24	1.00
4.842	2.646	1.875	2.646	r6	1.00	1.00	1.00	1.00

row 420

A_s sum	52.96 in^2	
P tension	2860 k-ult	0.9 * 52.96 * 60 ksi
A Circ	452 in^2	
A Rect	576 in^2	
A gross	452 in^2	

row 430

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN

TANK SUPPORT

PLASTIC CENTROID INERTIA CALCULATIONS — Circular. β = 90.00°

For Gross Section Including Steel

B	C	D	E	F	G	H	I	J	K	L	N
	-b1,1	b2,1	b3,1	b4,1	A	An*dist.	An d^2	A^*F_y	dist.$^*A^*F_y$	Ad^2	
An	8.04	8.04	8.04	8.04	32.18						
distance	21.354	22.125	21.354	19.158							
An*dist.	171.78	177.98	171.78	154.12		675.67					
d	9.35	10.13	9.35	7.16							
An d^2	703.94	824.68	703.94	412.21			2644.76				
A^*F_y	482.66	482.66	482.66	482.66				1930.65			
dist.$^*A^*F_y$	10307.03	10678.93	10307.03	9247.05					40540.04		row 440
Ad^2	703.94	824.68	703.94	412.21						2644.76	
	b1,2	b2,2	b3,2	b4,2							
A	8.04	74.33	0.00	8.04	90.42						
distance	19.158	20.480	-3.520	15.875							
An*dist.	154.12	1522.28	0.00	127.70		1804.10					
d	7.16	8.48	15.52	3.87							
An d^2	412.21	5345.11	0.00	120.78			5878.11				
A^*F_y	482.66	4459.81	0.00	482.66				5425.14			
dist.$^*A^*F_y$	9247.05	91336.91	0.00	7662.20					108246.2		row 450
Ad^2	412.21	5345.11	0.00	120.78						5878.11	
	b1,3	b2,3	b3,3	b4,3							
A	8.04	0.00	74.33	8.04	90.42						
distance	15.875	5.092	12.000	12.000							
An*dist.	127.70	0.00	891.96	96.53		1116.20					
d	3.87	6.91	0.00	0.00							
An d^2	120.78	0.00	0.00	0.00			120.78				
A^*F_y	482.66	0.00	4459.81	482.66				5425.14			
dist.$^*A^*F_y$	7662.20	0.00	53517.72	5791.96					66971.89		row 460
Ad^2	120.78	0.00	0.00	0.00						120.78	
	b1,4	b2,4	b3,4	b4,4							
A	8.04	74.33	0.00	8.04	90.42						
distance	12.000	12.000	0.000	8.125							
An*dist.	96.53	891.96	0.00	65.36		1053.86					
d	0.00	0.00	12.00	3.87							
An d^2	0.00	0.00	0.00	120.78			120.78				
A^*F_y	482.66	4459.81	0.00	482.66				5425.14			
dist.$^*A^*F_y$	5791.96	53517.72	0.00	3921.72					63231.40		
Ad^2	0.00	0.00	0.00	120.78						120.78	row 470
	b1,5	b2,5	b3,5	b4,5							
A	8.04	0.00	74.33	8.04	90.42						
distance	8.125	17.625	3.520	4.842							
An*dist.	65.36	0.00	261.64	38.95		365.95					
d	3.87	5.63	8.48	7.16							
An d^2	120.78	0.00	5345.11	412.21			5878.11				
A^*F_y	482.66	0.00	4459.81	482.66				5425.14			
dist.$^*A^*F_y$	3921.72	0.00	15698.53	2336.88					21957.13		row 480
Ad^2	120.78	0.00	5345.11	412.21						5878.11	
	b1,6	b2,6	b3,6	b4,6							
A*n	8.04	8.04	8.04	8.04	32.18						
distance	4.842	2.646	1.875	2.646							
An*dist.	38.95	21.28	15.08	21.28		96.59					
d	7.16	9.35	10.13	9.35							
An d^2	412.21	703.94	824.68	703.94			2644.76				
A^*F_y	482.66	482.66	482.66	482.66				1930.65			
dist.$^*A^*F_y$	2336.88	1276.89	904.99	1276.89					5795.65		row 490
Ad^2	412.21	703.94	824.68	703.94						2644.76	
					A*n	An*dist.	An d^2	$A^*f'_c$	dist.$^*A^*F_y$	Ad^2	
cg	12			Ag	452.4	5429	0.000	1809.6	21714.7		
d	0.00	ABS(12.00 - 12.00)		sum	878.4	10541	17287	4987.2	59845.9	2148.99 I reinforcing only	

CG_{xx}	12.00	in	
$I_{rectangular}$	27648	in^4	$24.0 * 24.0^3$ /12
$I_{circular}$	16286	in^4	$pd^4/64$ 3.14 * 24.0^4 /64
$I_{g\,xx}$ ↑	16286	in^4	Circular
PC_x	**12.00**	in	plastic centroid which yields uniform strain all across column from bottom fiber
I_{xx} ↑	18435	in^4	gross concrete includes ± AS — row 500

CONCRETE BIAXIAL COLUMN:
COMPOSITE CIRCULAR COLUMN
TANK SUPPORT

PLASTIC CENTROID INERTIA CALCULATIONS -- Continued — Circular, β = 90.00°

For Gross Section Including Steel

B	C	D	E	F	G	H	I	J	K	L	N
	-b1,1	b2,1	b3,1	b4,1	A	An*dist.	An d^2	A^*F_y	dist.*A^*F_y	Ad^2	
A * n	8.04	8.04	8.04	8.04	32.18						
distance	8.125	12.000	15.875	19.158							
An*dist.	525.80	776.55	1027.30	1239.78		3569.42					
d	3.87	0.00	3.87	7.16							
An d^2	971.61	0.00	971.61	3316.01			5259.2				
A^*F_y	482.66	482.66	482.66	482.66				1930.65			
dist.*A^*F_y	3921.72	5791.96	7662.20	9247.05					26622.93		row 510
Ad^2	120.78	0.00	120.78	412.21						653.78	
	b1,2	b2,2	b3,2	b4,2							
A *n	8.04	74.33	0.00	8.04	90.42						
distance	4.842	12.000	12.000	21.354							
An*dist.	313.31	7175.29	0.00	1381.90		8870.50					
d	7.16	0.00	0.00	9.35							
An d^2	3316.01	0.00	0.00	5662.74			8978.74				
A^*F_y	482.66	4459.81	0.00	482.66				5425.14			
dist.*A^*F_y	2336.88	53517.72	0.00	10307.03					66161.63		row 520
Ad^2	412.21	0.00	0.00	703.94						1116.15	
	b1,3	b2,3	b3,3	b4,3							
A *n	8.04	0.00	74.33	8.04	90.42						
distance	2.646	-10.587	20.480	22.125							
An*dist.	171.20	0.00	12245.83	1431.76		13848.78					
d	9.35	22.59	8.48	10.13							
An d^2	5662.74	0.00	42998.17	6634.01			55294.92				
A^*F_y	482.66	0.00	4459.81	482.66				5425.14			
dist.*A^*F_y	1276.89	0.00	91336.91	10678.93					103292.73		row 530
Ad^2	703.94	0.00	5345.11	824.68						6873.72	
	b1,4	b2,4	b3,4	b4,4							
A *n	8.04	74.33	0.00	8.04	90.42						
distance	1.875	3.520	6.000	21.354							
An*dist.	121.34	2104.75	0.00	1381.90		3607.98					
d	10.13	8.48	6.00	9.35							
An d^2	6634.01	42998.17	0.00	5662.74			55294.92				
A^*F_y	482.66	4459.81	0.00	482.66				5425.14			
dist.*A^*F_y	904.99	15698.53	0.00	10307.03					26910.56		row 540
Ad^2	824.68	5345.11	0.00	703.94						6873.72	
	b1,5	b2,5	b3,5	b4,5							
A *n	8.04	0.00	74.33	8.04	90.42						
distance	2.646	12.000	12.000	19.158							
An*dist.	171.20	0.00	7175.29	1239.78		8586.27					
d	9.35	0.00	0.00	7.16							
An d^2	5662.74	0.00	0.00	3316.01			8978.7				
A^*F_y	482.66	0.00	4459.81	482.66				5425.14			
dist.*A^*F_y	1276.89	0.00	53517.72	9247.05					64041.66		row 550
Ad^2	703.94	0.00	0.00	412.21						1116.15	
	b1,6	b2,6	b3,6	b4,6							
A *n	8.04	8.04	8.04	8.04	32.18						
distance	4.842	8.125	12.000	15.875							
An*dist.	313.31	525.80	776.55	1027.30		2642.95					
d	7.16	3.87	0.00	3.87							
An d^2	3316.01	971.61	0.00	971.61			5259.23				
A^*F_y	482.66	482.66	482.66	482.66				1930.65			
dist.*A^*F_y	2336.88	3921.72	5791.96	7662.20					19712.76		row 560
Ad^2	412.21	120.78	0.00	120.78						653.78	

					Ag	An*dist.	An d^2	A^*F_y	dist.*A^*F_y	Ad^2	
cg	12		Ag		452.4	5428.7	0.0	27143.4	325720.3		
d	0.00	ABS(12.00 - 12.00)	sum		878.4	10541.0	139065.8	30321.0	363851.5	2148.99 I reinforcing only	

CG_{yy}	12.00	in	
$I_{rectangular}$	27648	in^4	$24.0 * 24.0^3$ /12
$I_{circular}$	16286	in^4	$pd^4/64$ 3.14 * 24.0^4 /64
$I_{g\,yy}$ →	16286	in^4	Circular
PC_y →	**12.00**	in	plastic centroid which yields uniform strain all across column from left side fiber
I_{yy} →	18435	in^4	gross concrete includes ± AS

row 570

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN

TANK SUPPORT

A B C D E F G H I J K L M N

RADIUS OF GYRATION

Circular, β = 90.00°

r_x ↑	4.6 in	$\sqrt{I_{xx}/\text{area}}$ ↑
r_y →	4.6 in	$\sqrt{I_{yy}/\text{area}}$ →

PLASTIC CENTROID STRAIN CALCULATIONS

β	1.5708 radians	counter clockwise from the x-axis
	90.0000	
sin β	1.0000	
cos β	0.0000	
tan β	1.18E+11	

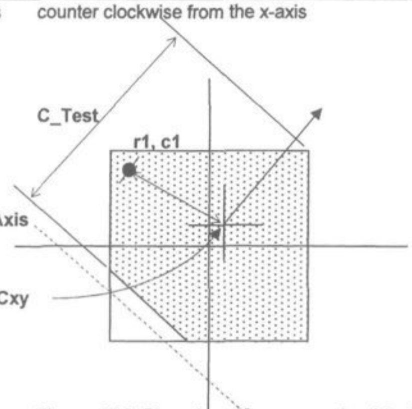


Figure 45-8 Plan view of compression block and reinforcing.

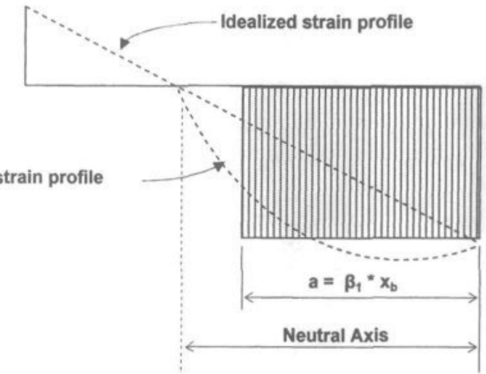


Figure 45-9 The strain profile diagram.

Distance of Reinforcing from PCxy

[(12.00 - 8.13)^2 + (12.00 - 21.35)^2]^0.5

	c1	c2	c3	c4
PC r1 c1	**10.13**	10.13	10.13	10.12
r2	10.12	8.48	15.52	10.13
r3	10.13	23.62	8.48	10.13
r4	10.13	8.48	13.42	10.13
r5	10.13	5.63	8.48	10.12
r6	10.12	10.13	10.13	10.13

E_s	Young's modulus of steel, ε_S = strain
ε_s	strain
ε_{cu}	concrete crushing strain, 0.003, unitless
ε_y	strain at first yield, unitless
ε'_s	strain in compression reinforcing, unitless
ε_t	allowable tension reinforcing strain, unitless
x_b ,x bal	distance of the neutral axis to the extreme fiber in compression noted as C_test/β_1 in this template, inches.

row 600

E_s * STRAIN

C_TEST **11.000** in — referenced from the summary window to the extreme fiber (up and right) perpendicular to the axis through intersection of PCx and PCy

x bal /d = ε'_c = 0.003 — Strain Profile See 02 ACI 318 10.3.2 and 10.3.3

$\varepsilon'_c + \varepsilon_t$ = 0.003 + f_y /29,000

row 610

x bal = 87 d /(87 + 60)

8.125 - $Pcx

horizontal	c1	c2	c3	c4
r1	**-3.875**	0.000	3.875	7.158 inch
r2	-7.158	0.000	0.000	9.354
r3	-9.354	-22.587	8.480	10.125
r4	-10.125	-8.480	-6.000	9.354
r5	-9.354	0.000	0.000	7.158
r6	-7.158	-3.875	0.000	3.875

row 620

21.354 - $Pcy

vertical	c1	c2	c3	c4
r1	**9.354**	10.125	9.354	7.158 inch
r2	7.158	8.480	-15.520	3.875
r3	3.875	-6.908	0.000	0.000
r4	0.000	0.000	-12.000	-3.875
r5	-3.875	5.625	-8.480	-7.158
r6	-7.158	-9.354	-10.125	-9.354

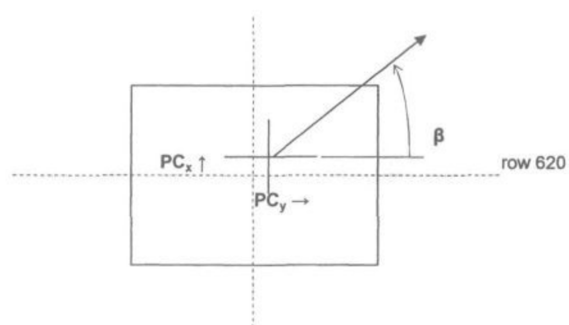


Figure 45-10 Rotation of the X-axis about PCxy.

row 630

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN

TANK SUPPORT

A B C D E F G H I J K L M N

REINFORCING LOCATION LOGIC Circular. β = 90.00°

Horizontal Direction

-1	1	1	1
-1	1	1	1
-1	-1	1	1
-1	-1	-1	1
-1	1	1	1
-1	-1	1	1

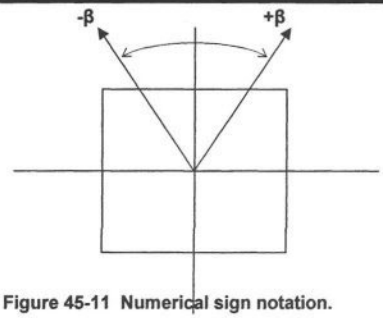


Figure 45-11 Numerical sign notation.

Vertical Direction row 640

1	1	1	1
1	1	-1	1
1	-1	1	1
1	1	-1	-1
-1	1	-1	-1
-1	-1	-1	-1

add pi()/2 to vertical direction

0	0	0	0
0	0	1	0
0	-1	0	0
0	0	-1	1
-1	0	1	1
-1	-1	1	1

row 650

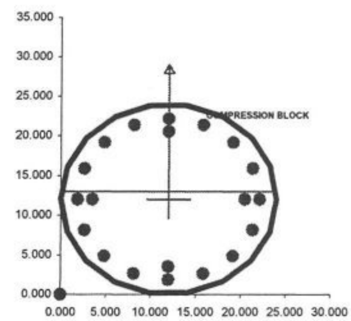


Figure 45-12 Direction of loads.

Angle of Reinforcing from PCxy Vertical

ABS(ATAN(IF(0 , 9.354 /(-3.875 + 0.000001), -3.875 /(9.354 + 0.000001))) - PI() /2 * 0) * -1

angle	c1	c2	c3	c4						
r1	**-0.3927**	0.0000	0.3927	0.7854	radians	-22.5	0.0	22.5	45.0	degrees
r2	-0.7854	0.0000	3.1416	1.1781		-45.0	0.0	180.0	67.5	
r3	-1.1781	-1.8676	1.5708	1.5708		-67.5	-107.0	90.0	90.0	
r4	-1.5708	-1.5708	-2.6779	1.9635		-90.0	-90.0	-153.4	112.5	
r5	-1.9635	0.0000	3.1416	2.3562		-112.5	0.0	180.0	135.0	
r6	-2.3562	-2.7489	3.1416	2.7489		-135.0	-157.5	180.0	157.5	

row 660

Difference between β and Reinforcing Angle

$β + R1 C1

1.5708 + -0.3927

	c1	c2	c3	c4						
r1	**1.1781**	1.5708	1.9635	2.3562		67.5	90.0	112.5	135.0	degrees
r2	0.7854	1.5708	4.7124	2.7489	radians	45.0	90.0	270.0	157.5	
r3	0.3927	-0.2968	3.1416	3.1416		22.5	-17.0	180.0	180.0	
r4	0.0000	0.0000	-1.1071	3.5343		0.0	0.0	-63.4	202.5	
r5	-0.3927	1.5708	4.7124	3.9270		-22.5	90.0	270.0	225.0	
r6	-0.7854	-1.1781	4.7124	4.3197		-45.0	-67.5	270.0	247.5	

row 670

Distance of Rebar from Rotating X-axis Through PCxy

SIN(r1 c1) * PC_r1_c1

SIN(1.1781) * 10.13

	c1	c2	c3	c4	
r1	**9.354**	10.125	9.354	7.158	inch
r2	7.158	8.480	-15.520	3.875	
r3	3.875	-6.908	0.000	0.000	
r4	0.000	0.000	-12.000	-3.875	
r5	-3.875	5.625	-8.480	-7.158	
r6	-7.158	-9.354	-10.125	-9.354	

row 680

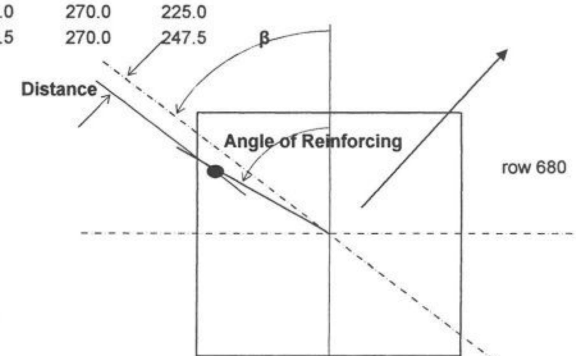


Figure 45-13 Distance of reinforcing from the rotationg vertical axis through PCxy.

row 690

A	B	C	D	E	F	G	H	I	J	K	L	M	N

REINFORCING STRAIN — Circular. β = 90.00°

C_Test	11.000 in		reference
β_1	0.85 unitless		reference
N.A.	12.941		11.000 /0.85 neutral axis
strain u	0.002069 unitless		60 /29000 strain to first yield, reference
β	1.571 radians		reference 90.0000 degrees

			C_Test	to PCxy		N.A.	to PCxy
x top→pt	12.0000	x begin→	12.0000	0.0000	x begin→	12.0000	0.0000
y top ↑ pt	24.0000	y begin↑	13.0000	1.0000	y begin↑	11.0588	-0.9412

add xy	0.9412 in	
max diag c	24.000 in	max circular diagonal
Max Diag	24.000 in	

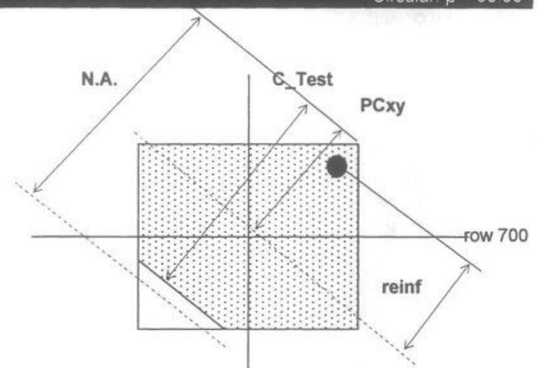


Figure 45-14 The extreme fiber to the neutral axis and the relative strain in the reinforcing.

Relative Strain

9.354 /12.941

	c1	c2	c3	c4
r1	**0.723**	0.782	0.723	0.626 unitless
r2	0.553	0.655	-1.199	0.299
r3	0.299	-0.534	0.000	0.000
r4	0.000	0.000	-0.927	-0.299
r5	-0.299	0.435	-0.655	-0.553
r6	-0.553	-0.723	-0.782	-0.723

0.002069

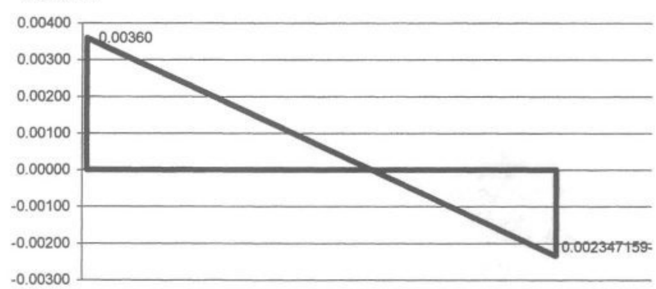


Figure 45-15 Strain Profile

Reinforcing

Where: 87 = 0.003*29000

87 * 0.723

	c1	c2	c3	c4
r1	**62.89**	68.07	62.89	54.45 k
r2	48.12	57.01	-104.34	26.05
r3	26.05	-46.44	0.00	0.00
r4	0.00	0.00	-80.67	-26.05
r5	-26.05	37.82	-57.01	-48.12
r6	-48.12	-62.89	-68.07	-62.89

STRAIN DIAGRAM

X	0.01	1	1	0.01	0.01
Y	0.00360	-0.002347	0	0	0.0036

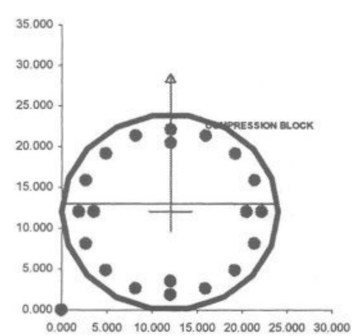
row 730

LIMIT f_y

IF(ABS(Reinforcing) > F_y, fs_1, c1 /ABS(fs_1, c1) * F_y, fs_1, c1)

IF(ABS(62.89) > 60, 62.9 /ABS(62.89) * 60, 62.89)

	c1	c2	c3	c4
fs_1 c1	**60.0**	60.0	60.0	54.5 ksi
fs_2	48.1	57.0	-60.0	26.0
fs_3	26.0	-46.4	0.0	0.0
fs_4	0.0	0.0	-60.0	-26.0
fs_5	-26.0	37.8	-57.0	-48.1
fs_6	-48.1	-60.0	-60.0	-60.0



row 740

Figure 45-16 Load direction with reinforcing location and compression block.

row 750

A	B	C	D	E	F	G	H	I	J	K	L	M	N

For P_n — Circular. β = 90.00°

Tension Steel k

A_r1_c1 * fs_1_c1 * (fs_1_c1 < 0)
1.00 * 60.0 * (60.0 < 0)

PC_x ↑
PC_y →

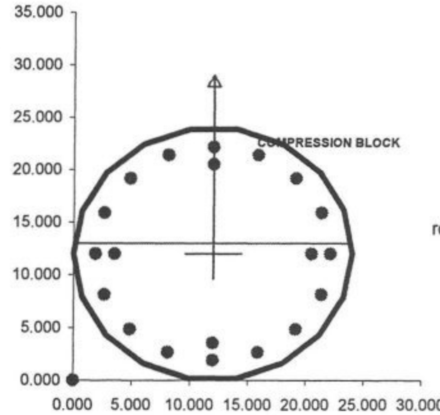
	c1	c2	c3	c4	
Ts_1	**0.0**	0.0	0.0	0.0	k
Ts_2	0.0	0.0	0.0	0.0	
Ts_3	0.0	0.0	0.0	0.0	
Ts_4	0.0	0.0	0.0	-26.0	
Ts_5	-26.0	0.0	-526.8	-48.1	row 760
Ts_6	-48.1	-60.0	-60.0	-60.0	

STL_COMP **1** logic — 1 for $f'_S = E_S * e_S$ compression reinforcing compatibility switch
0 for $f'_S = 0$ when $f'_S < f_y$

Compression Steel k

A_r1_c1 * fs_1_c1 * (fs_1_c1 > 0)
1.00 * 60.0 * (60.0 > 0)

	c1	c2	c3	c4	
Cs_1	**60.000**	60.0	60.0	54.5	k
Cs_2	48.1	526.8	0.0	26.0	
Cs_3	26.0	0.0	0.0	0.0	
Cs_4	0.0	0.0	0.0	0.0	
Cs_5	0.0	0.0	0.0	0.0	
Cs_6	0.0	0.0	0.0	0.0	



row 770

C_Test A_S

Area C_c 2.89 unitless — Deduct the area of reinforcing $A_s * \beta_1 * f'_c$ of steel for C_c

Figure 45-17 Load direction with reinforcing location and compression block.

row 780

T_s*arm

-Ts_1, c1 * PC_r1_c1 — row 790
- 0.0 * 10.1

0.0	0.0	0.0	0.0	k-in
0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	
0.0	0.0	0.0	263.8	
263.8	0.0	4466.9	487.2	
487.2	607.5	607.5	607.5	

C_s * arm — row 800

Cs_1, c1 * PC_r1_c1
60.0 * 10.1

607.5	607.5	607.5	551.2	k-in
487.2	4466.9	0.0	263.8	
263.8	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	

row 810

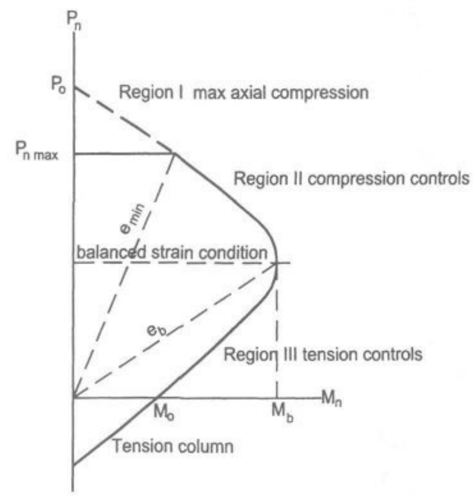
CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN
TANK SUPPORT

A	B	C	D	E	F	G	H	I	J	K	L	M	N

For $P_n e_n$ — Circular, β = 90.00°

	0	logic	Circular
T_S arm	7791	k-in	T_S * arm from centroid
C_S arm	7855	k-in	
C_C arm	3577	k-in	$C_{C\ conc}$ * $C_{L\ area}$
			IF(0, 844.6 * 6.50, 634.6 * 5.64)
$P_n e_n$	19224	k-in	Ts_arm + Cs_arm + Cc_arm
	1602.0	k-ft	
e_n	29.99	in	$P_n e_n$ / P_n
			19,224.21 / 640.92
Sym	1	logic	$+A_s = -A_s$ symmetry
$f_y \le 60$	1	logic	$f_y \le 60$

row 820



row 830

Figure 45-18 The interaction diagram for axial load and bending moment.

Y_{xx}↑	0.844	unitless	(h - d' - d_s) /h ≥ 0.70 ACI 9.3.2.2
Y_{yy}→	0.844	unitless	(h - d' - d_s) /h ≥ 0.70
Y	1	logic	Y_{xx} and $Y_{yy} \ge 0.70$

Where:
$f_y \le 60$ ksi
and reinforcing is symmetrical row 840
(h - d' - d_s) /h ≥ 0.70
ø may be increased linearly to 0.90
as øP_n decreases from 0.10 $f'_c A_g$ to 0
ACI 9.3.2.2

$ø_1$	0.75	unitless	Tied columns = 0.7, Spiral tied columns = 0.75 ACI 9.3.2.2
$ø_1 P_n$	480.7	k	$ø_1$ * P_n
			0.75 * 640.9
Tie	0.15		Tied columns = 0.2, Spiral tied columns = 0.15
			(0 = 1) * 0.2 + (0 = 0) * 0.15
_.1$A_g f'_c$	230	k	0.10 * length * width * f'_c ACI 9.3.2.2
			0.10 * 24.00 * 24.00 * 4
$ø_2$	0.75	unitless	max ($ø_1$, 0.90 - (Tie * $ø_1 P_n$ /_.1$A_g f'_c$)) ACI 9.3.2.2
			MAX(0.75, (0.9 - (0.15 * 481 /230)))
$ø_2 P_n$	481	k	$ø_2$ * P_n
			0.75 * 640.9
$ø_3$	0.75		max ($ø_1$, 0.90 - (Tie * $ø_2 P_n$ /_.1$A_g f'_c$))
			MAX(0.75, (0.9 - (0.15 * 481 /230)))
$ø_3 P_n$	480.7	k	$ø_3$ * P_n * (sum(Sym + [$f_y \le 60$] + Y) = 3)
			0.75 * 641 * ((1 + 1 + 1) = 3)
			where conditions of symmetry, $f_y \le 60$, and Y_{xx} & $Y_{yy} \ge 0.70$ are met

row 850

row 860

row 870

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN
TANK SUPPORT

A B C D E F G H I J K L M N

MATH for RECTANGULAR ROTATING COMPRESSION BLOCK — Circular, β = 90.00°

L	**24.00** in	referenced from above	
W	**24.00** in	reference	
β_{input}	**1.5708** radians	reference	
	90.0000 degrees		
tan β	1.18E+11 unitless		
sin β	1.0000 unitless		
cos β	0.0000 unitless		

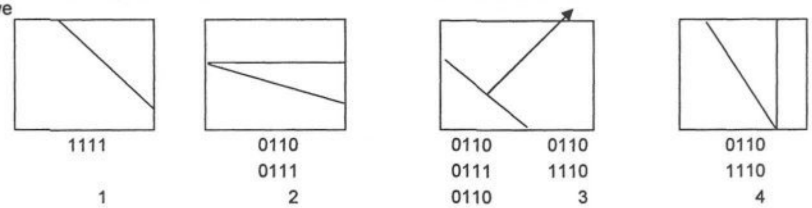


Figure 45-19 Area computation logic diagrams.

row 880

PCx	12.00 in	PCx top	*12.00 in*
PCy	12.00 in	PCy right	12.00 in
A diag	0.785 rad		
	45.000 deg		
diag	16.971 in	PC x, y to top right corner	
sweep	1 logic	$\beta_{input} \geq$ A diag	
diff	0.7854 rad	difference between diagonal and load direction	
	45.0000 deg		

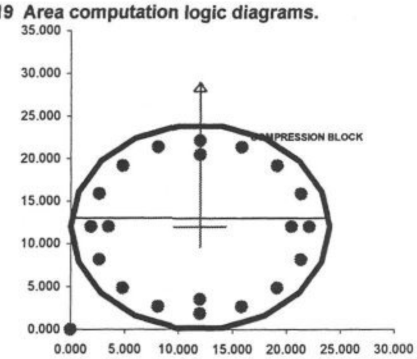


Figure 45-20 Load direction and compression block.

row 890

x top→pt	12.0000	**0.0000**	12.0000 pt	the extreme fiber up and right
y top ↑ pt	12.0000	**12.0000**	24.0000	

C_Test 11.000

For 0 pressure line intersection with perimeter

x top→pt	12.000	x diag→	0.0000								
y top ↑ pt	*24.000*	y diag↑	*11.0000* x begin→	**12.000**	*x top→*	*10999906*		x top→	**0**	0
			y begin↑	**13.000**	y top ↑	0.000		y top ↑	**13**	1
					x bot→	24.000		x bot→	**24**	1
logic	0110	0110			y bot ↑	0.000		y bot ↑	**13**	1

	B	C	E	F	G	H	I	J	K
logic	0111	1110	A triangle						
x →	24.00	0.00	1111	0111	0110	1110			
y ↑	11.000	24	24.000	24.000	24.000	24.000			
A rect	264.0	0.0	11.000	0.000	13.000	24.000			
			132.0	0.0	156.0	288.0			
logic	1	0	0	1	0	0			
logic			0	2	0	0	sum A	2	
A rect	264.0	0.0	0.0	0.0	0.0	0.0	264.00 in²	area of compression block	
CG y→	12.00	24.00	16.00	16.00	16.00	16.00	in		
CG x ↑	18.50	12.00	20.33	13.00	8.67	16.00	in		
							sum Ad	CG from bottom left	CG from top right
Ad y→	3168.0	0.0	*0.0*	*0.0*	*0.0*	*0.0*	3168 in³	12 in→	12 in←
Ad x ↑	4884.0	0.0	0.0	0.0	0.0	0.0	4884 in³	18.5 in ↑	5.5 in ↓
CG PCy→	0.0000 in→								
CG PCx↑	6.5000 in ↑								

row 910

CG PCxy	6.5000 in	sum(d*A) / AREA from P_{Cx} and $_y$

row 920

$C_{C\ concrete}$	845 k	0.85 * f'_C * AREA -sum(d < C_TEST A_S) w/o deduct for comp st'l area
		0.85 * 4.00 * 264.00 - SUM(52.96)
P_n	851 k	$T_s + C_s + C_c$ the nominal axial load strength
		19,946 k + 78,679 k + 845 k
Conc	1778 k	0.85 * f'_C * (Lxx * Wyy - sum(Area steel))
$Steel_{rect}$	3177.6 k	f_y * sum(Area steel)
P_o	4956 k	Conc + $Steel_{rectangular}$
$P_{n\ max}$	3402 k	P_o*$ø_1$ (Design Strength Factor)

row 930

CONCRETE BIAXIAL COLUMN: COMPOSITE CIRCULAR COLUMN

TANK SUPPORT

MATH for SEMICIRCULAR ROTATING COMPRESSION BLOCK — Circular, β = 90.00°

L_{xx}	**24.0** in	referenced from above
W_{yy}	**24.0** in	
	24.0 in	
	33.9 in	
max diag	24.0 in	
C Test	**11** in	compress block reference

For a bearing area as a partially loaded semicircle to full semicircle

leg b	11.96 in	((24.00 /2)^2 - (24.00 /2 - 11.000)^2)^0.5
chord	23.92 in	
leg c	12.00 in	radius
angle α	1.4874 radians	atan(11.96 /(24.00 /2 - 11.00))
$A_{segment}$	202.2 in^2	(24.00 /2)^2 * (1.4874 - SIN(1.4874) * COS(1.4874))
$A_{semi\ c}$	226.2 in^2	area of semicircle
$A_{bearing\ 1}$	202.2 in^2	
xc	5.64 in	cg of bearing area 1
xc semi c	5.09 in	
$xc_{bearing\ 1}$	5.64 in	

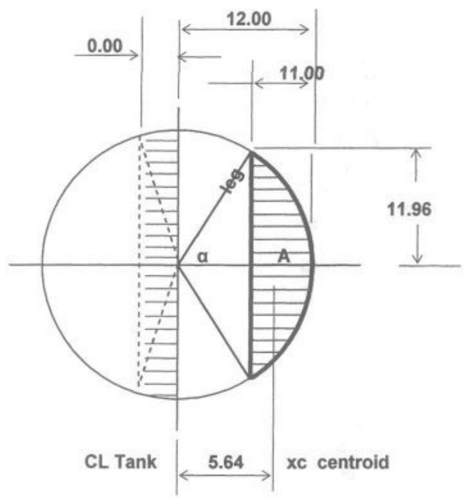


Figure 45-21 Diagram of a circular segment

row 940

row 950

For a bearing area as a loaded semicircle to fully loaded circle

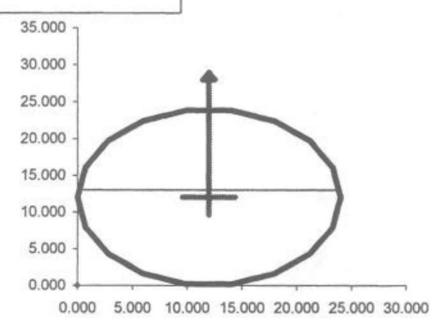
angle α	4.6290 radians	
$A_{segment}$	202.2 in^2	
$A_{bearing\ 2}$	428.4 in^2	$A_{semi\ c}$ - $A_{segment}$
xc seg	-5.64 in	
$xc_{bearing\ 2}$	5.35 in	
A sum	202.2 in^2	
xc sum	-5.70 in	

row 960

$C_{L\ area}$	5.64 in	to CG of compression area

$C_{C\ concrete}$	635 k	0.85 * f'c * AREA -sum(d < C_TEST A_S) w/o deduct for comp st'l area 0.85 * 4.00 * 202.22 - SUM(52.96)

P_n	641 k	$T_s + C_s + C_c$ nominal axial load strength -855 k + 861 k + 635 k
Conc	Circular	
Circular	1358 k	0.85 * f'c * (p r^2 - sum(Area steel))
Rectangle	1905	
	1358	
Steel	3178 k	f_y * sum(Area steel)
P_o	4536 k	Conc + $Steel_{circular}$
$P_{n\ max}$	3402 k	P_o*$ø_1$ (Design Strength Factor)



row 970

Figure 45-22 Direction of loads.

Rectangular / Circular Switch

Shape	C alpha	Circular
	0 Logic	0 = Circular, 1 = Rectangular
$C_{L\ area}$	5.64	
$C_{C\ concrete}$	635	
P_n	641 k	
Conc	1358 k	
St'l	3178 k	
P_o	4536 k	
$P_{n\ max}$	3402 k	

row 980

row 990

CONCRETE BIAXIAL COLUMN
PARTIAL SHELL
TANK SUPPORT

46

Christy
18:24
12/20/05

Segment for composite column calculation

ENGINEERING with the SPREADSHEET

46 Partial Shell.xls

A B C D E F G H I J K

PARTIAL SHELL MATH

diameter 1	**24.00**	inch	outside diameter of shell
b1 rise	**3.52**	in	depth of arc
t shell	**0.50**	in	thickness of shell
leg	8.48	in	
angle	0.7860	radians	ACOS(8.48 /(24.00 /2))
	45.0	degrees	
xc	10.577	in	
area 1	113.19		
area 2	103.95		
area net	9.24	in^2	area of segment
area gross	36.13	in^2	
leg vert	8.49	in	

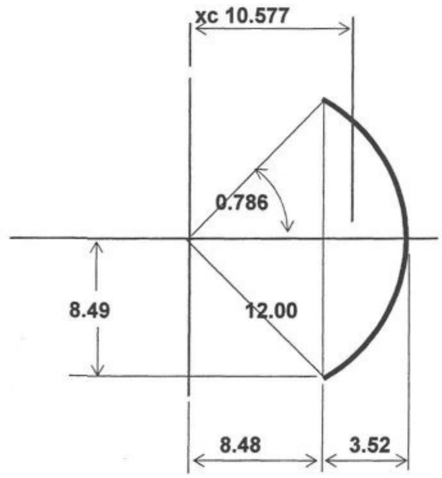


Figure 46-1 One quarter segment of a circle.

ENTIRE SHELL MATH

diameter	24.00	in	outside diameter of shell
t shell	0.50	in	thickness of shell
area	36.13	in^2	
c	12.0	in	24.00 /2
I	2549	in^4	PI() * (24.00^4 - (24.00 - 2 * 0.50)^4)/64
S	212.4	in^3	2,549 /12.0
r	8.40	in	(2,549 /36.13)^0.5

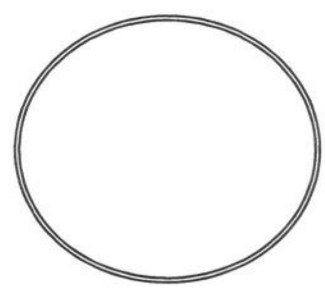


Figure 46-2 The entire shell cross section

CONCRETE BIAXIAL COLUMN: PHOTOGRAPHS

TANK SUPPORT

A B C D E F G H I J K L M N

CONSTRUCTION PHOTOGRAPHS

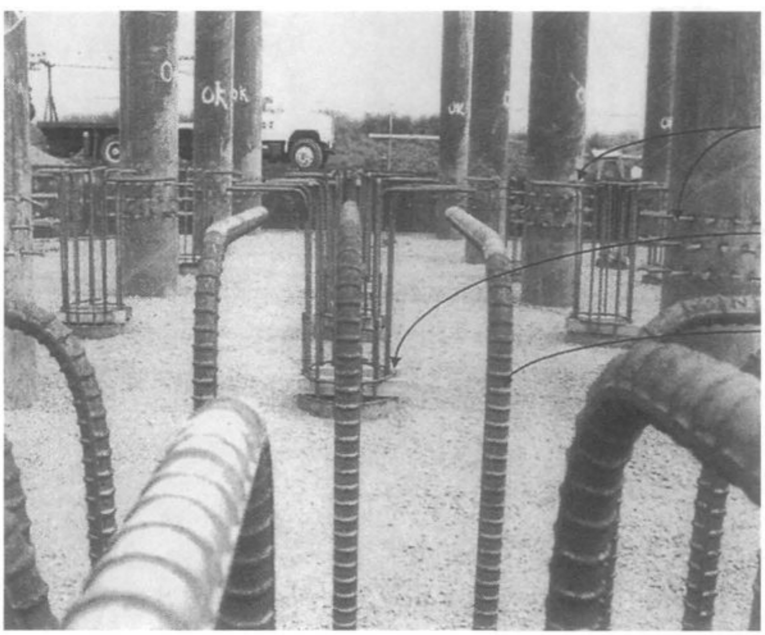
- These pile columns will support the elevated deck as well as the pile cap. The pile cap will distribute column loads to all of the piling.
- Vibratory compactor.
- Temporary caps to keep debris out of the piling.
- This gravel mat provides a clean, hard working surface as well as a quality subgrade for the concrete pile cap.

row 20

row 30

Figure 47-1 Compacting the gravel housekeeping mat.

row 40



- Headed weld studs on all through pile columns.
- Temporary wood braces to position the reinforcing cages.
- Reinforcing cage inside of the piling. Bars have tails for better development and construction purposes.

row 50

row 60

Figure 47-2 This is a view of pile columns above grade and pile columns with rebar cages at grade.

row 70

CONCRETE BIAXIAL COLUMN: PHOTOGRAPHS

TANK SUPPORT

A B C D E F G H I J K L M N

CONSTRUCTION PHOTOGRAPHS -- Continued

row 80

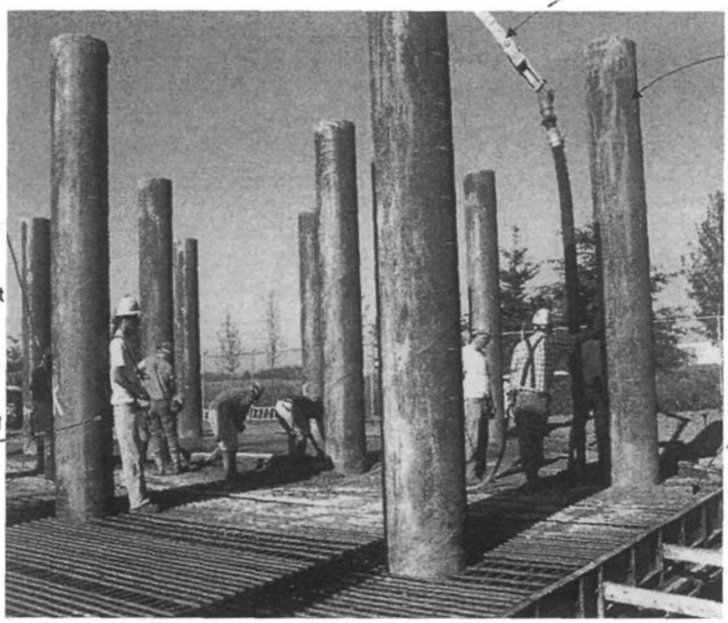
As one truck moves out another moves in. The concrete pumper is behind the trucks. 500 cubic yards of concrete were placed in about three hours.

row 90

Figure 47-3 Two trucks are shown in position to load the pump hopper.

row 100

The concrete pumper boom.



These piling will recieve reinforcing cages and concrete in the next few days.

row 110

The man in the yellow hardhat and white shirt guides the boom with a radio transmitter. The transmitter has two control sticks much like the transmitter for radio controlled airplanes.

Formwork is tied off to the pile columns and buttresed against the sides of the excavation.

Pressure at the bottom of the forms will be 600 psf. Total force against the forms will be 1,200 Lb. / linear foot of length.

Figure 47-4 This view shows the concrete placers, the pump boom operator, and the concrete finishers (in the background).

row 130

CONCRETE SHEAR
TANK SUPPORT

At column 39 to 139 Seismic

y

A B C D E F G H I J K L M N

BEARING ON CONCRETE

f'c	**4**	ksi	ultimate strength of concrete
Punching	**290**	k_ult	**SEISMIC ultimate load**
ratio	**1**	unitless	LRFD factor
P_ult	290.0	k_ult	required
f_brg	3.4	ksi_ult	0.85 * f'_c allowable bearing on concrete
Φ_{brg}	0.7		
A_1 req'd	122	in^2	11.0 in on a side minimum
A_2	**452**	in^2	area of supporting surface not to exceed 2 ACI 10.17.1
multiplier	2.00		A_1 / A_2
A req'd	61	in^2	

A $_2$ is measured along this plane

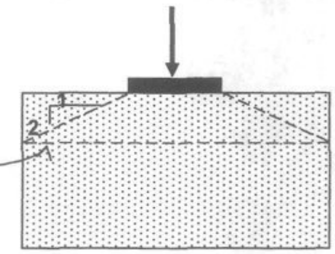


Figure 48-1 Bearing area and edge distance

CIRCULAR PUNCHING SHEAR

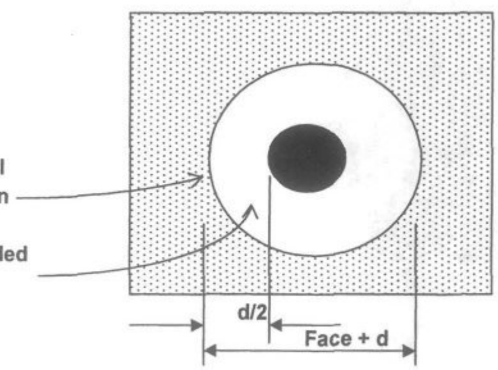
dia	**24.00**	in	
A_pl	452.4	in^2	
		452 in² > 122 in²	
P_ult	290.0	k_ult	1.0 * 290.0
β_c	1.00	unitless	ratio = 1 for circular column
d	**36.0**	in	depth to tension reinforcing
b_o	188	in	(dia + d)*pi
Ao	6786	in^2	b_o * d 36.0 * 188
V_c 33	**2575**	k	02 ACI 11.12.2.1 (11-33) 6 * (4 * 1000)^0.5 /1000 * 188 * 36.0 where (2 + 4/βc) = 6
α_s	**40**	unitless	factor
V_c 34	**4137**	k	$(\alpha_s d / b_o + 2) \sqrt{f'_c}\, b_o\, d$ 02 ACI 11.12.2.1 (11-34) (40 * 36.0 /188.5 + 2) * (4 * 1000)^0.5 /1000 * 188 * 36.0
V_c 35	**1717**	k	$A_o 4 \sqrt{f'_c}$ 02 ACI 11.12.2.1 (11-35) 6,786 * 4 * (4 * 1000)^0.5 * 0.85 /1000

α_s 40 for interior columns
30 for edge columns
20 for corner columns

V_c min	**1717**	k	Use minimum V_c for punching shear.

Φ_v	0.85	unitless	strength reduction factor
V_u	**1459**	k ult OK	Φ V_c minimum
		290.0 < 1,459 k ultimate allowed	

convert circular column to equivalent square



row 30

Figure 48-2 Shear punching in plan view.

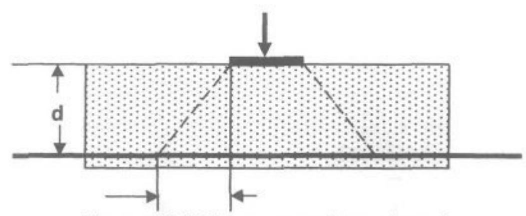


Figure 48-3 Shear cone dimensions in elevation view.

row 60

CONCRETE SHEAR
TANK SUPPORT

At column 39 to 139 Seismic

A B C D E F G H I J K L M N

STIRRUP REINFORCING

b_1	60.0	in	width of critical section
s	**4.0**	in	stirrup / tie spacing ≤ d/2 or 24"
f_y	**40**	ksi	stirrup / tie yield strength
A_v	**0**	in^2	sum of area for all vertical bars to resist shear

=0.31*10 ← **Note: Calculation for A_v is done in the input cell. The actual calculation is copied to an adjacent cell and parked with the [space bar] to show the math.**

row 70

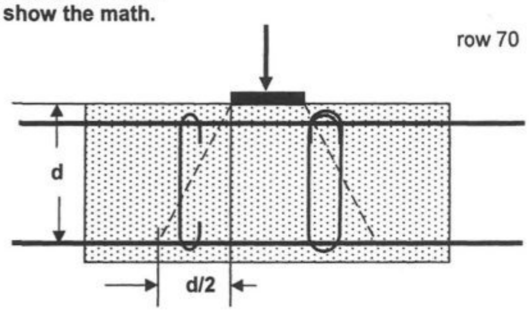


Figure 48-4 Shear reinforcing through the shear cone.

V_s	0.0	k	A_v F_y d /s ACI 11.5.6.2 0.00 * 40 * 36.0 /4.0

V_u 1459.2 k-ult Φ (V_c minimum + V_s)
0.85 * (1,717 + 0.0)
OK 290.0 required < 1,459.2 k ultimate allowed

INCLINED BAR REINFORCING

f'c	**4**	ksi
V_u reqd	**290.0**	k ult
d	**36.0**	in
V_c	**1716.7**	k ult
Φv	0.85	unitless

Per ACI Commentary R11.12.3 In slabs 10" and thinner, shear reinforcement should be enclosed stirrups with a longitudinal bar at each corner.

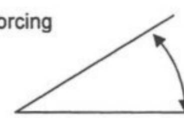
b_1 60.0 in width of critical section

row 90

α **60.0** degrees angle of shear bars from the plane of beam/column reinforcing
1.047 radians

f_y **60** ksi stirrup / tie yield strength

A_v **9.6** in^2 **=0.6*12**
sum of area for all bars to resist shear



V_s 498.8 k A_v F_y sin α ACI 11.5.6.5 (11-17)
9.60 * 60 * sin 60.0

but not greater than:

b_w **72.0** in width of tributary beam

V_s 491.8 k $3\sqrt{f'_c}\, b_w\, d$
3 * (4.00 * 1000)^0.5 * 72.0 * 36.00 /1000

V_s use	491.8	k

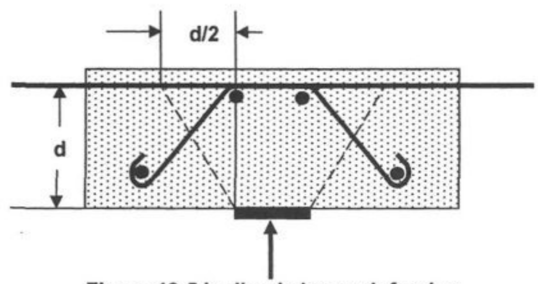


Figure 48-5 Inclined shear reinforcing.

V_u 1877.2 k-ult Φ (V_c minimum + V_s)
0.85 * (1,717 + 491.8)
OK 290.0 required < 1,877.2 k ultimate allowed

row 110

CONCRETE SHEAR
TANK SUPPORT

At column 39 to 139 Seismic

A B C D E F G H I J K L M N

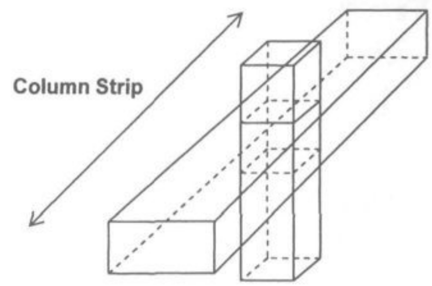
TORSION

Torsion per ACI 11.6.3

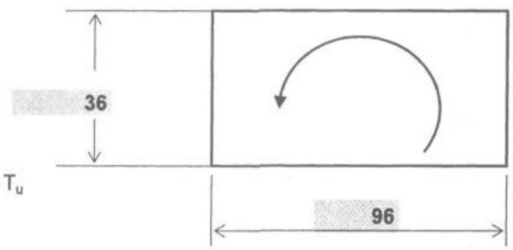
T_u **1006286** in-lb/ft ult **=1174*1000*12 /14**
ultimate torsional moment

f'_c **4** ksi
$\Phi_{torsion}$ **0.75** factor

A_{oh} **3456** in^2
A_{cp} **3456** in^2
p_{cp} **264** in



row 120



For Nonprestressed members
Torsional effects on bending and shear can be neglected when $T_{u\ Limit} < T_u$

row 130

$T_{u\ Limit}$ 2146025 in-lb ult $\Phi \sqrt{f'_c}\ (A_{cp}^2 / p_{cp})$
1 logic
OK Tu limit ≥ Tu required
Torsion reinforcing not required

Figure 48-6 Beam torsion shear.

ρ_h **0.007** unitless **=12*0.6/(24*42)**
ratio of horizontal shear reinforcing area
to gross area of the vertical concrete section

A_{oh} area enclosed by the centerline of the closed torsion reinforcement, in^2

A_{cp} area enclosed by the outside perimeter of the concrete cross section, in^2

p_{cp} outside perimeter of the concrete cross section, in

T 1 0.013 $(V_u / b_w\ d)^2$
(290 /(72.0 * 36.0))^2

T 2 0.000 $(T_u\ \rho_h / 1.7\ A_{oh}^2)^2$
(1,006,286 * 0.007 /(1.7 * 3,456^2))^2

T required 0.11 k-in ult $\sqrt{(V_u / b_w\ d)^2 + (T_u\ \rho_h / 1.7\ A_{oh}^2)^2}$

T provided 0.99 k-in ult $\Phi_v\ (V_c / b_w\ d + 8 \sqrt{f'_c})$
0.85 * (1,716.7 /(72.0 * 36.0) + 8 * (4 * 1000)^0.5 /1000)

row 150

row 160

CONCRETE SHEAR
TANK SUPPORT

At column 39 to 139 Seismic

y

A B C D E F G H I J K L M N

BEAM SHEAR

V beam	**230.0**	k	**=460/2 column punching divided by 2 sides**
ratio beam	**1**	unitless	fluid + DL
Vu req'd	230.0	k_ult	***seismic***
f'_c	**4**	ksi	
d	**36**	in	depth to reinforcing
b_w	**96**	in	width of beam or tributary slab
V_c	437.2	k	$2\ \sqrt{f'_c}\ b_w * d$ ACI 11.3.1.1
			2 * (4 * 1000)^0.5 * 36.0 * 96 /1000
Φ	0.85	unitless	strength reduction factor
V_u allow	371.6	k_ult	0.85 * 437.2
	1	logic	
		OK 371.6 > 230.0 k_ult required	
s	**6.0**	in	stirrup / tie spacing $\leq$ d/2 or 24"
f_y	**40**	ksi	stirrup / tie yield strength
A_v	**0.00**	in^2	sum of area for all bars to resist shear
		=0.2*12	
A_v req'd	0.72	in^2	$50 * b_w \cdot s\ /f_y$ ACI 11.5.5.2
			50 * 96 * 6.0 /40.00 /1000
V_s	0.0	k	$A_v\ F_y\ d\ /s$ ACI 11.5.6.2
			0.00 * 40 * 36.0 /6.0
V_u allow	371.6	k-ult	$\Phi\ (V_c + V_s)$
			0.85 * (437.2 + 0)

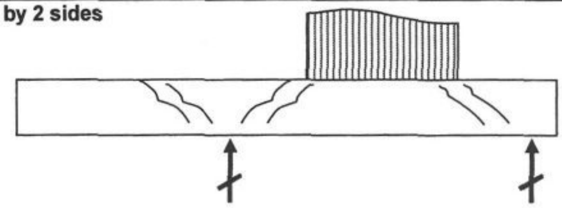


Figure 48-7 Beam shear elevation.

Bar	Area
10M	0.12
15M	0.27
20M	0.49
25M	0.76
30M	1.1
35M	1.49
45M	2.47
55M	3.68
0	0
3	0.11
4	0.20
5	0.31
6	0.44
7	0.6
8	0.79
9	1.00
10	1.27
11	1.56
14	2.25
18	4.00

row 180

row 190

FOR MEMBERS SUBJECT TO SHEAR AND FLEXURE

A_s	**7.2**	in^2	area of tension reinforcing
			=0.6*12
ρ_w	0.0021	unitless	density of tension reinforcing
M_u	**1174.0**	k-ft ult	factored ultimate moment
limit	7.1		$V_u\ d\ /\ M_u \leq 1.0$
	1.0		$(\ 1.9\ \sqrt{f'_c} + 2500\ \rho_w\ V_u\ d\ /\ M_u)\ b_w\ d$ ACI 11.3.2.1
a	0.120		1.9 * (4.0 * 1000)^0.5 /1000
b	0.005		2500 * 0.0021 * 1.0 /1000
V_c	433.3	k	(0.120 + 0.005) * 96.0 * 36.0
V_c limit	765.0	k	$3.5\ \sqrt{f'_c}\ b_w * d$ ACI 11.3.2.1
V_c	433.3	k	minimum(V_c limit, V_c)
V_u allow	368.3	k-ult	$\Phi\ (V_c + V_s)$
	1	logic	
		OK 368.3 > 230.0 k_ult required	

row 200

row 210

A B C D E F G H I J K L M N

PHOTOGRAPHS

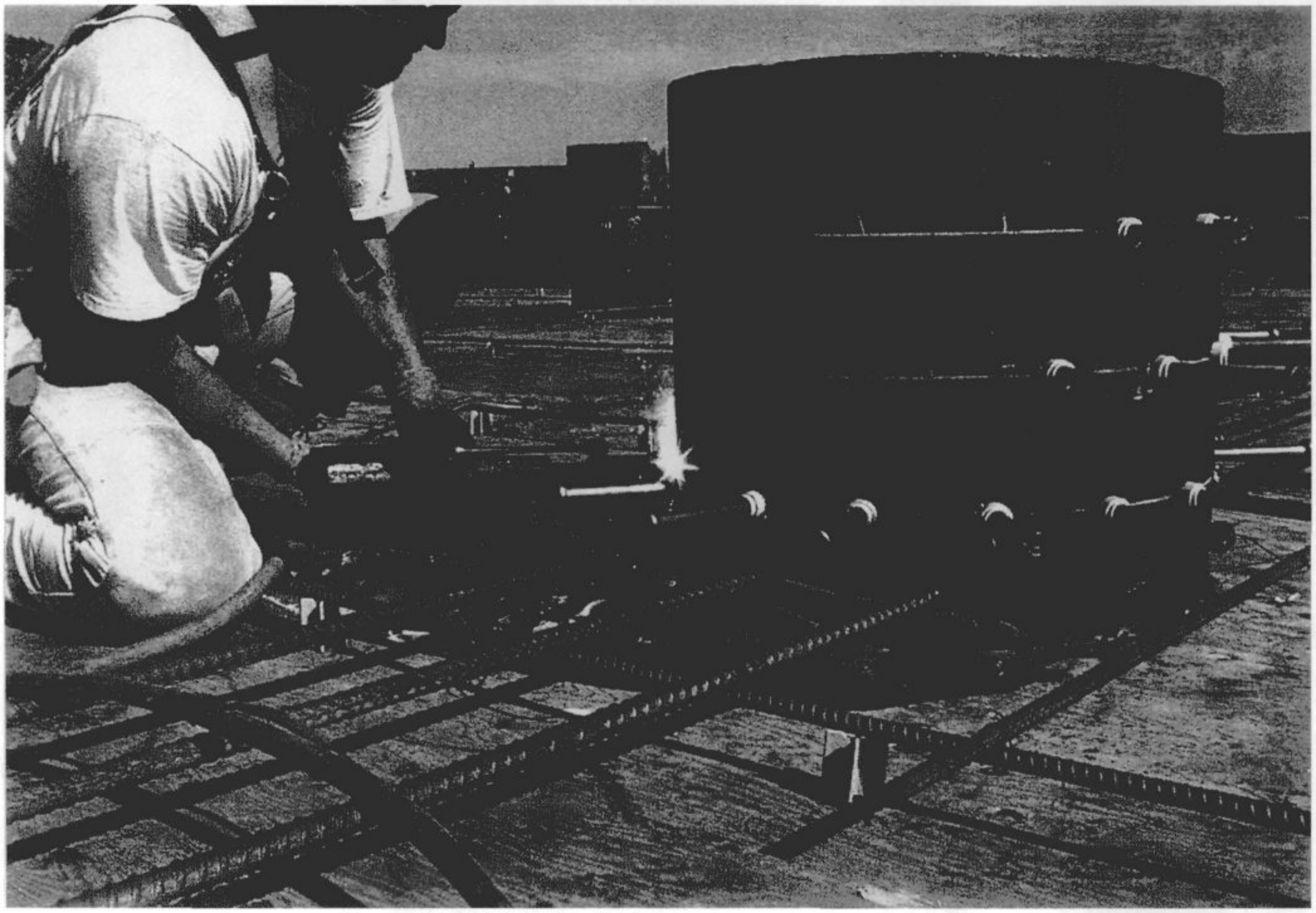


Figure 48-8 Weld stud application.

Weld stud application requires a large generator. The welded end of the stud contains the weld material and flux. The white, porcelan ferrules contain the electric arc, flux, and weld material.

After welding, the ferrule is broken off and discarded.

You can visit the Nelson Weld Stud site at:
http://www.nelsonstud.com

For evaluation reports, go to the International Building Codes Evaluation Service website at:
http://www.icbo.org/ICBO_ES/

On February 1, 2003, ICBO ES formally joined with the National Evaluation Service, BOCAI evaluation services, and SBCCI PST & ESI in the new ICC Evaluation Service, Inc. (ICC-ES).
ICC-ES is a subsidiary of the International Code Council.
The web site address will change in time.

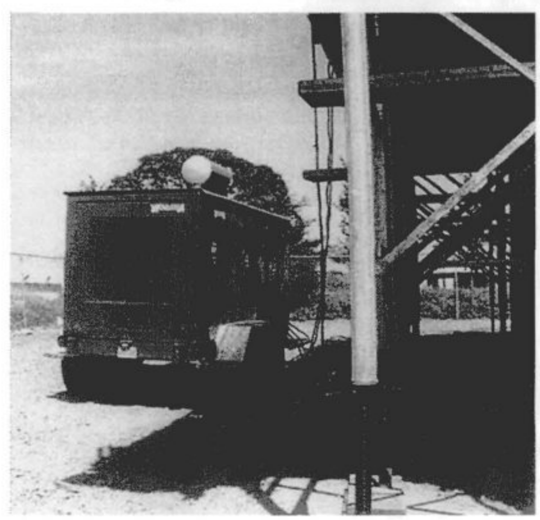
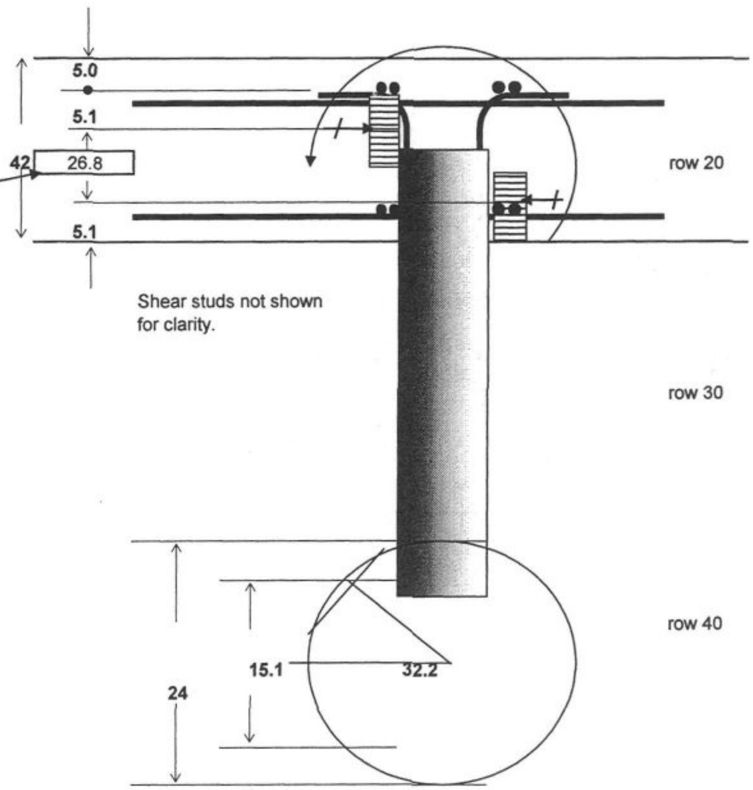


Figure 48-9 The big, portable weld stud generator. row 270

DESIGN FOR MOMENT TRANSFER WITHOUT THE SHEAR TRANSFER MECHANISM

In designing for moment transfer without shear transfer mechanism, the resulting answer will be more conservative.

Mu	**1174**	k-ft ult	
width	**15.1**	in	width of comression blocks
depth	**12**	in	depth of compression blocks
f'c	**4**	ksi	
β	**0.85**		for 4 ksi concrete
block	10.2	in	0.85*depth
Cc	524	k ult	
arm	2.24	ft	compare
	26.9	in	



row 20

Whitney's compression blocks act on the top and bottom of the pile and cage column.
The width of 15.1" is an estimate of usable bearing width.

angle	0.56159	radians
	32.2	degrees

row 30

At the greatest angle, the bearing surface will be sloping away from the compression force by about 32 degrees.

The theoretical stress blocks are confined by the matrix of reinforcing top and bottom.

row 40

Figure 49-1 An elevation and plan view of the slab column moment transfer mechanism.

row 50

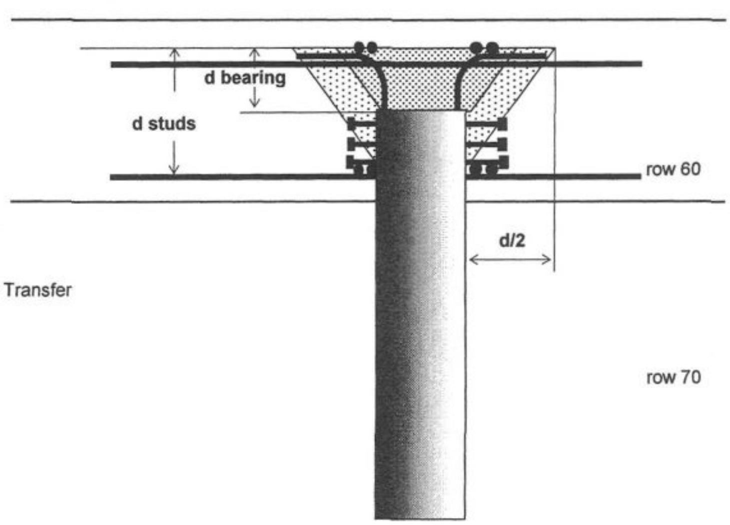
SHEAR STUD PUNCHING

Part of the punching shear is resolved by the traditional punching cone of **d_bearing** depth.
The rest of the punching shear is taken care of by the headed weld studs.

Because some of the moment from column to slab is transfered as a type of punching shear, this arrangement is also compared to the unit stress required on the critical column face times the punching area:

$$v_u \text{ sum} * (\text{column } \varnothing + \text{d\_studs}) * \pi * \text{d\_studs}$$

v_u sum (the unit shear) is determined in the Slab-Column Moment Shear Transfer calculations and can be found in the box just above row 70.



row 60

row 70

Figure 49-2 The two shear cones generated by the column.

row 80

COLUMN DECK INTERFACE
TANK SUPPORT
COLUMN-SLAB MOMENT TRANSFER

PHOTOGRAPHS

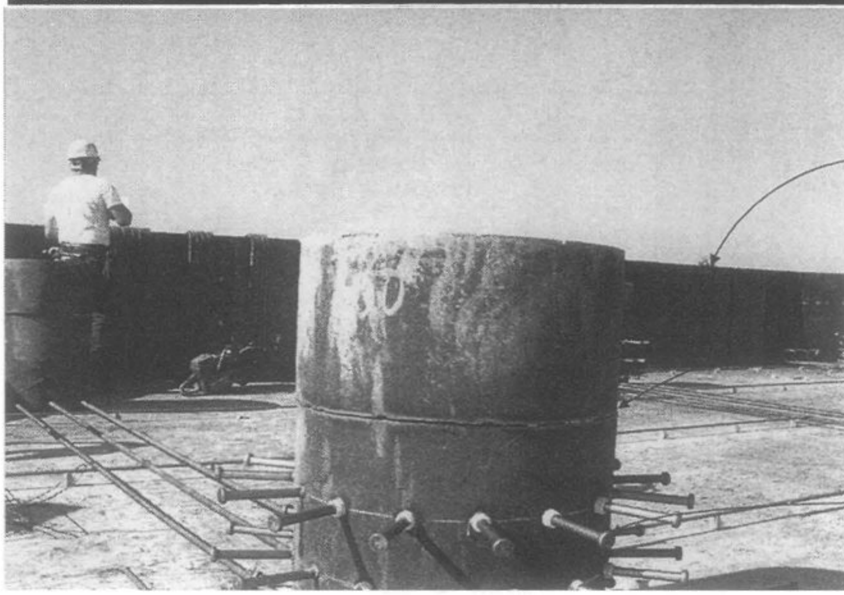


Figure 49-3 Column cut height and the shear stud pattern.

Upper deck forms.

row 90

Pile column cut height. This height was chosen for the depth of shear cone it would generate and still provide a column sufficient to resist seismicly generated moments.

row 100

The weld stud pattern. The white rings at the connection are ferrules which contain the flux and weld material during the application process. The ferrules are later broken off and swept away.

row 110

Hammer mark

Bending this stud down is best done with a 10 pound hammer. The stud should withstand bending until it is parallel with the pile face. The ability to bend at this joint shows ductility and strength of the weld.

row 120

It is very unsettling to strike one of these studs and have it snap off. Usually, the craftsman breaks off studs and replaces them with a new, better connected stud.

row 130

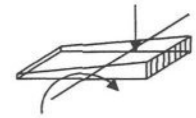
Figure 49-4 Testing the weld stud with a BFH (big fat hammer).

row 140

row 150

SLAB-COLUMN MOMENT SHEAR TRANSFER
TANK SUPPORT

Column Moment Transfer to Deck
At column 39 to 139 Seismic



A B C D E F G H I J K L M N

SHEAR

L_1	**14**	ft	
L_2	**14**	ft	
dia	**24.0**	in	circular column
L_n	12.0	ft	
d	**36.0**	in	
b_1	60.0	in	
b_o	188	in	shear cone perimeter ACI 11.12.1.2 perimeter needs not to approach the periphery of the loaded area closer than d/2
Mu req	**1174**	k-ft_ult	
V_u req	**460**	k_ult	
V_c	**1459**	k	as defined in ACI 11.12.2.1 per 11.12.6.2

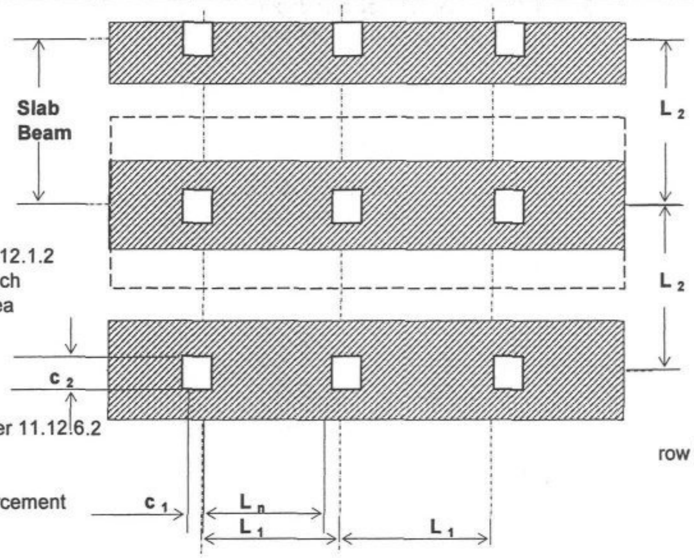


Figure 50-1 FRAMING LAYOUT PLAN

Note: Get V_c from punching shear calculations.

row 30

Φ	0.85	unitless	strength reduction factor
Φ v_n	0.183	ksi	members without shear reinforcement ACI 11.12.6.2 (11-40) 0.85 * 1,459 /(188 * 36.0)
V_s	**0.0**	k	additional shear capacity due to stirrups and bent-up bars
Φ v_n	0.183	ksi	Φ v_n = v_u 0.85 * (1,459.0 + 0.0) /(188.5 * 36.0)

row 40

v_u max	*0.183*	*ksi_ult*	*maximum shear stress allowed*

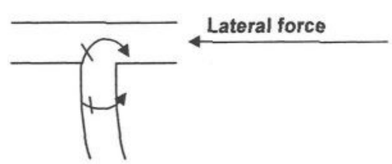


Figure 50-2 -- The column-slab joint applied force and reaction.

J_c	1296000		36.0 * (24.0 + 36.0)^3 /6
	466560		(24.0 + 36.0) * 36.0^3 /6
	3888000		36.0 * (24.0 + 36.0) * (24.0 + 36.0)^2 /2
J_c	5650560	in^4	polar moment of inertia
A_c	6786	in^2	punching shear area 188.5 * 36.0

row 50

γ_f	0.60	ratio	% of moment transfered by flexure ACI 13.5.3.2 (13-1) $1 /(1 + 2/3 * \sqrt{1.0 /1.0}$
γ_v	0.40	ratio	% of moment transfered by shear ACI 11.12.6.1 (11-41) 1 - 0.60
$v_{u\ transfer}$	0.073	ksi	moment transfered by shear V_u / A_c + γ_v M_u b_1 / J_c 460.0 /6,786 + 0.40 * 1,174.0 * 60.0 /5,650,560
V_u	157.2	k_ult	0.073 * 36.0 * 60.0
$v_{u\ punching}$	0.068	ksi_ult	460.0 /6,786 required

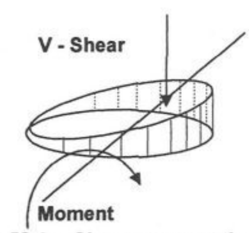


Figure 50-3 -- Shear stress at the critical section.

Note: This is similar to: P/A ± Mc/I

v_u sum	0.141	ksi_ult	v_u transfer + v_u punching required 0.068 + 0.073
	OK 0.141 required < 0.183 allowed		
	303.6	k_ult	v_u b_1 d punching shear at critical face 0.141 * 60.0 * 36.0

row 70

CONSULTING COMPANY

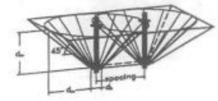
ENGINEERING with the SPREADSHEET

BOLT GROUP PULLOUT
TANK SUPPORT

At column 39 to 139 Seismic

51

Christy
18:37
12/20/05



51 Bolt Group Pullout.xls

A B C D E F G H I J K L M N

'ANCHORAGE TO CONCRETE, Tension -- fully encased bolt UBC 1923.2

Inspect	**1.3**	unitless	inspection factor
T_tens	**1.00**	k_ult	required tension /bolt - ultimate
V_shear	**358**	k_ult	required shear /group - ultimate
	650	**-292**	**shear cone at the top of the pile**
P_U	**1.3**	k_ult	tension
V_U	**465.4**	k_ult	shear
d bolt	**0.75**	in	anchor shank diameter
A_b	0.44	in^2	net cross-section area of bolt
d_e	**10**	in	edge distance **toward** loaded edge
Edge 2	**3**	in	edge distance **away** from loaded edge
	1	logic	
	0	logic	
Edge	0	logic	
f_{ut}	**58**	k/in^2	ultimate tensile strength
P_{ss}	**23.1**	k_ult	$0.9 * A_b * f_{ut}$ 0.9 * 0.44 in² * 58 ksi
V_{ss}	**19.2**	k_ult	$0.75 * A_b * f_{ut}$ 0.75 * 0.44 in² * 58 ksi
λ	**1.00**	unitless	concrete factor
d_h	**1.25**	in	Tributary area of plate 1.2 in² or head Actual plate may be rectangular
d_m	**5.8**	in	depth of embedded plate for pullout
f'_C	**4**	k/in^2	compressive strength of concrete
A_P	130	in^2	effective area of projected cone onto the surface of the slab ((1.3 + 2 * 5.8) /2)² * π
P_C	**8.2**	k_ult	$\lambda * A_P * \sqrt{f'_C}$ UBC 1923.3.2 $1.00 * 130 in^2 * \sqrt{4,000}$ /1000
V_C	22.4	k_ult	$800 * A_b * \sqrt{f'_C}$ UBC 1923.3.3 $800 * 0.44 * \sqrt{4 * 1000}$ /1000 for bolts more than 10 diameters towards the loaded edge V_c not governed by A_b
V_C	39.7	k_ult	$2\,\pi\,d_e^2\,\lambda\,f'_C$ $2 * \pi * 10.0^2 * 1.00 * \sqrt{4 * 1000}$ /1000
V_C	**39.7**	k_ult	
Φ	**0.85**	unitless	0.85 for confined anchor embedment 0.65 for unconfined anchor embedment UBC 1923.3.2 execption

Surface area of projected cone

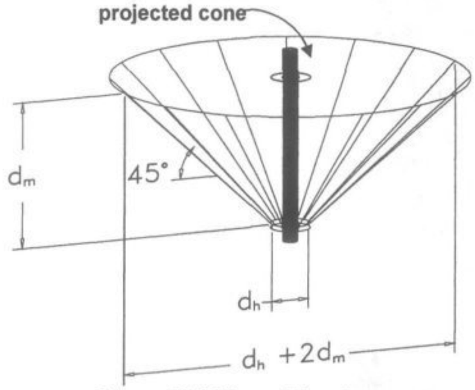


Figure 51-1 View of the shear cone.

INSPECTION -- UBC 1923.2 row 30

1.3 Special inspection provided for bolts anchored in compression zone

2 No special inspection

2 Special inspection provided for bolts anchored in tension zone

3 No special inspection for bolts anchored in the tension zone

λ UBC 1923.3.2 row 40

1.00 normal weight concrete

0.85 sand light weight concrete

0.75 all-light weight concrete

Edge distance

Shear loading more than 10 diameters from the loaded edge.

row 50

Tension or shear away from an edge more than 5 diameters away and with reinforcing to prevent concrete in tension failure.

Edge distance not less than 4 diameters in any case.

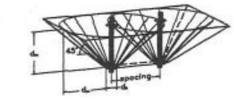
row 60

$$\frac{1}{\Phi}\left[\left(\frac{P_u}{P_c}\right)^{5/3} + \left(\frac{V_u}{V_c}\right)^{5/3}\right] = \frac{1}{0.85}\left[\left(\frac{1.3}{8.2}\right)^{5/3} + \left(\frac{465.4}{39.7}\right)^{5/3}\right] = \mathbf{71.112} > \mathbf{1.000}\ !!!$$

$$\left[\frac{P_u}{P_{SS}}\right]^2 + \left[\frac{V_u}{V_{SS}}\right]^2 = \left[\frac{1.3}{23.1}\right]^2 + \left[\frac{465.4}{19.2}\right]^2 = \mathbf{586.478} > \mathbf{1}\ !!!$$

row 70

BOLT GROUP PULLOUT
TANK SUPPORT



At column 39 to 139 Seismic

UBC 1923.2 ANCHORAGE TO CONCRETE, Tension -- fully encased group of bolts

For a group of connectors, use the area of a truncated pyramid projected onto the surface of the slab

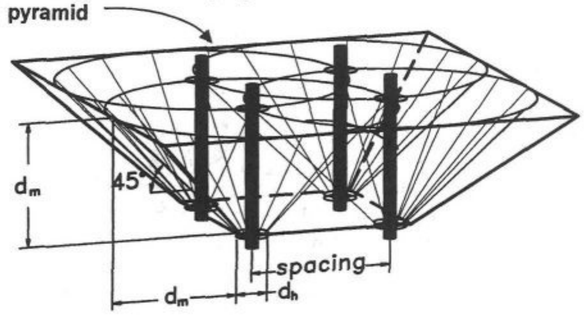


Figure 51-2 View of grouped shear cones.

P_U	**1.3**	k_ult	tension
V_U	**465.4**	k_ult	shear
spacing_	**5.0**	in	symetrical in both directions
number_	**42**	unit	4, 9, 16, 25, etcetera
	1	logic	OK 5.0 ≤ 2 * 5.8 Use Bolt Group
P_{ss}	**968.6**	k_ult	0.9 * A_b * f_{ut} * number_ 0.9 * 0.44 in² * 58 ksi * 42
V_{ss}	**807.1**	k_ult	0.75 * A_b * f_{ut} * number_ 0.75 * 0.44 in² * 58 ksi * 42
Length	40.25	in	2 * 5.8 dm + (5.0 spacing) *($\sqrt{42 \text{ number}}$ - 1) + 1.25 dh
Width	40.25	in	2 * 5.8 dm + (5.0 spacing) *($\sqrt{42 \text{ number}}$ - 1) + 1.25 dh
A_p	1620.4	in²	Length * Width
P_c	**102.5**	k_ult.	I * A_p * $\sqrt{f_c}$ UBC 1923.3.2 1.00 * 1,620 in² * (4,000 ksi)^0.5
V_c	**1669.0**	k_ult.	V_c * number 39.7 * 42

row 90

row 100

$$\frac{1}{\Phi}\left[\left[\frac{P_u}{P_c}\right]^{5/3}+\left[\frac{V_u}{V_c}\right]^{5/3}\right] = \frac{1}{0.85}\left[\frac{1.3}{102.5}\,^{\wedge 5/3} + \frac{465.4}{1669.0}\,^{\wedge 5/3}\right] = \mathbf{0.141} < 1.000 \text{ OK}$$

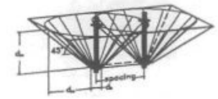
$$\left[\frac{P_u}{P_{ss}}\right]^2+\left[\frac{V_u}{V_{ss}}\right]^2 = \left[\frac{1.3}{968.6}\right]^2 + \left[\frac{465.4}{807.1}\right]^2 = \mathbf{0.332} < 1.000 \text{ OK}$$

row 110

HILTI	F_v	F_u
HAS Std / A36	36	**58**
HAS Super /B7	105	**125**
HAS SS /A 304 SS	65	**100**
A307		**60**
A108 studs		**65**
A325 to 1" Grade 5, B7	92	**120**
A325-1 1 1/8" to 1 1/2"	81	**105**
A490 Gr 8, 1/2" - 1 1/2"	120	**150**
A354 Gr. BD 1/2" to 2 1/2"	120	**150**

row 120

row 130



A B C D E F G H I J K L M N

ANCHORAGE TO CONCRETE, Shear -- fully encased bolt UBC 1923.3.3

PARSING UBC 1923.3.2 *WHERE*:

A_p = the effective area of the **projection**
of an assumed concrete failure surface
upon the surface from which the anchor protudes.

For a single anchor or for an anchor group
where the distance between anchors is equal to or greater than twice their embedment length,
the surface is assumed to be that of a truncated cone
radiating at a 45 degree slope form the bearing edge of the anchor
toward the surface from which the anchor protrudes.

The effective area is the **projection** of the cone on this surface.

For an anchor which is perpendicular to the surface from which it protrudes,
the effective area is a circle.

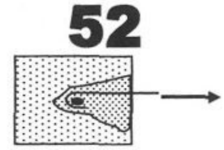
For an anchor group where the distance between anchors is less than twice their embedment lengths,
the failure surface is assumed to be that of a truncated pyramid
radiating at a 45 degree slope from the bearing edge of the anchor group
toward the surface from which the anchors protrude.

The effective area is the **projection** of this truncated pyramid on this surface.

In addition, for thin sections with anchor groups,
the failure surface shall be assumed to follow the extension of this slope through to the far side rather than be truncated,
and the failure mode resulting in the lower value of FP_c shall control.

Do you really think that you can understand this without diagrams?

EMBED
TANK SUPPORT

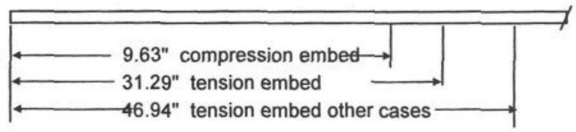


52 Embed.xls

A B C D E F G H I J K L M N

TENSION DEVELOPMENT # 7, fy 60 ksi, f'c 4

Bar_#	**7**	0.88" dia.	bar size Fy 60 ksi/f'c 4.0 ksi see below
top bar	**1**	0/1 yes	no / yes more than 12" concrete below bar
L available	**63**	in	available space for embed or hook (for flag)
f_y	**60**	k/in^2	rebar yeild strength
f'_c	**4**	k/in^2	concrete compressive strength



cover	*3*	*in*	*concrete side cover*
	0	logic	
spacing	**4**	in !!	6" c-c spacing & 3" min. side cover require
	1	logic	
a	1.3	unit	1+ top_bar * 0.3

Figure 52-1 Reinforcing embed lengths.

Coating per 99 ACI 12.2.4

Epoxy coated bars and wire w/ less *than 3 d_b cover or 6 d_b spacing*	1.5
Other epoxy coated wire	1.2
Uncoated reinforcement	1.0

for epoxy bars use 1.5

b	**1**	factor	coating factor for plain and/or epoxy coated rebar ACI 12.2.4 not to exceed a * b = 1.7
ab	1.3	unitless	=MIN(b * TOP, 1.7)
g	1.0	unitless	bar size factor #3 to #6 = 0.8, #7 and larger = 1.0
l	**1**	factor	for lightweight concrete = 1.3 or f_{ct} factor, normalweight concrete = 1.0
A_{tr}	**0.6**	in^2	area of transverse reinforcing at spacing s 99 ACI 12.2.4
f_{yt}	40	ksi	yeild strength of transverse reinforcement, ties, and stirrups
s	6	in	spacing of transverse reinforcement
n	2	quantity	number of bars being developed
K_{tr}	1.333	unitless	$=A_{tr} * f_{yt}/(1500\ s * n)$ K_{tr} may = 0 for simplification even when transverse reinforcing is present

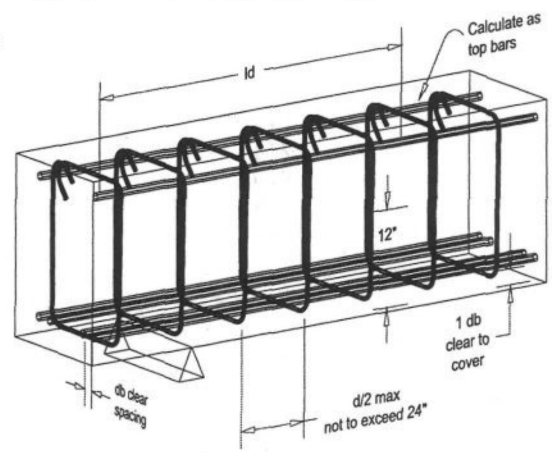


Figure 52-2 Reinforcing embed lengths.

row 40

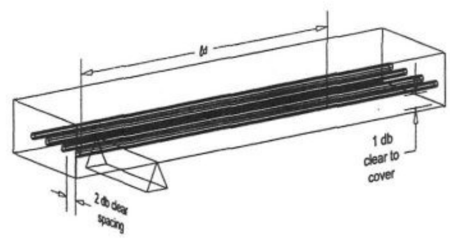


Figure 52-3 Reinforcing clearances in a beam.

Calculation 1 where spacing $\geq d_b$, clear cover $\geq d_b$, and stirrups or ties throughout l_d at or better than code minimum

l_d / d_b	49.3	$f_y * a * b * l / (25 * \sqrt{f'_c})$	tension for #3 - #6
l_d / d_b	61.7	$f_y * a * b * l / (20 * \sqrt{f'_c})$	tension for #7 and larger

Calculation 2 Other cases

l_d / d_b	74.0	$3 * f_y * a * b * l / (50 * \sqrt{f'_c})$	tension for #3 - #6
l_d / d_b	92.5	$3 * f_y * a * b * l / (40 * \sqrt{f'_c})$	tension for #7 and larger

Calculation 3 minimum for calculations 1 and 2 where minimum embed = 12" 99 ACI 12.2.3

	2.5	=min((cover + K_{tr}) /(bar/8), 2.5)
l_d / d_b	37.0	= $3/40 * f_y / \sqrt{f'_c} * ab * g * l$ / min((cover + K_{tr}) /(bar/8), 2.5)

row 60

As req / As	**58** %	As required / As provided flexural reinforcing except:
	0.58 fraction	member is a part of primary load resisting system 99 ACI 12.11.2 required shrinkage and temperature reinforcement 99 ACI 7.12.2.3 bottom bars within the column strip 99 ACI 13.3.8.5

37.9 tension for #3 - #6 $=f_y*1000/(25\sqrt{f_c*1000})$
47.4 tension for #7 and larger

row 70

A B C D E F G H I J K L M N

TENSION DEVELOPMENT -- Continued

7, fy 60 ksi, f'c 4

DEVELOPMENT TABLE Based Upon Fy 60 ksi, f'c 4 ksi, Beta 1.0, reinforcing above 12" of the bottom of the pour

Bar Size#	Area in^2		Tension Calc 1 Basic		Tension Calc 2 Other cases	K_{tr}	Calc 3 minimum	l_{db} in	Compression l_{db_c} in
0	0	0					92.5	0	0
3	0.11	18.5	**21.5**	27.7	**21.5**	2.500	37.0	6.94	**4.13**
4	0.20	24.7	**21.5**	37.0	**21.5**	2.500	37.0	12.33	**5.50**
5	0.31	30.8	**21.5**	46.2	**26.8**	2.500	37.0	19.27	**6.88**
6	0.44	37.0	**21.5**	55.5	**32.2**	2.500	37.0	27.75	**8.25**
7	0.60	54.0	**31.3**	80.9	**46.9**	2.500	37.0	47.21	**9.63**
8	0.79	61.7	**35.8**	92.5	**53.6**	2.500	37.0	61.66	**11.00**
9	1.00	69.4	**40.2**	104.1	**60.4**	2.500	37.0	78.04	**12.38**
10	1.27	77.1	**44.7**	115.6	**67.1**	2.500	37.0	96.35	**13.76**
11	1.56	84.8	**49.2**	127.2	**73.8**	2.500	37.0	116.58	**15.13**
14	2.25	107.9	**62.6**	161.9	**93.9**	2.476	37.4	188.85	**19.26**
18	4.00	138.7	**80.5**	208.1	**120.7**	1.926	48.0	312.18	**24.76**

row 80

Area	0.60	in^2	for #7 bar
l_d_table	31.3	in	l_{db} basic bar development length
l_d_table	46.9	in	l_{db} bar development length for "other casses"

row 90

. **Tension embedment 31.3 required <63.00" allowed**

. **Tension embedment 46.9 required <63.00" allowed for other cases**

COMPRESSION DEVELOPMENT

l_{db_c} is the basic compression development length without factors.

l_{db_c}	16.6	in	=0.02 * bar /8 * f_y / f'c*1000 * 1000	99 ACI 12.3.2
	15.8	in	=0.0003 * bar /8 * f_y * 1000	
As req / As	**58**	%	As required / As provided compression reinforcing	
	0.58	fraction		
Spiral / tie	**1**	factor	where reinforcing is confined per 99 ACI 12.3.3.2 use 0.75 -- when reinforced with spirals or ties (per (	
l_{db}	9.6	in		

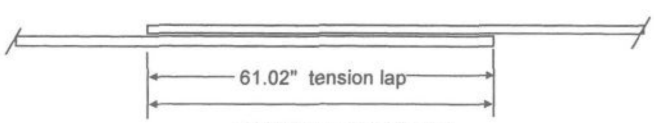


Figure 52-4 Reinforcing lap distances.

F_y	**60**	ksi	yeild strength of reinforcing
f'_c	**3**	ksi	compressive strength of concrete
f_{ct}	**1**	ksi	average splitting tensile strength of lightweight aggregate concrete
	1.0	factor	=MAX (6.7$\sqrt{f'_c}$ / f_{ct}, 1.0)
l	**1.0**	factor	for lightweight concrete = 1.3 or fct factor, normalweight concrete = 1.0
P_t	32.4	k_ult	0.9 * Fy * area

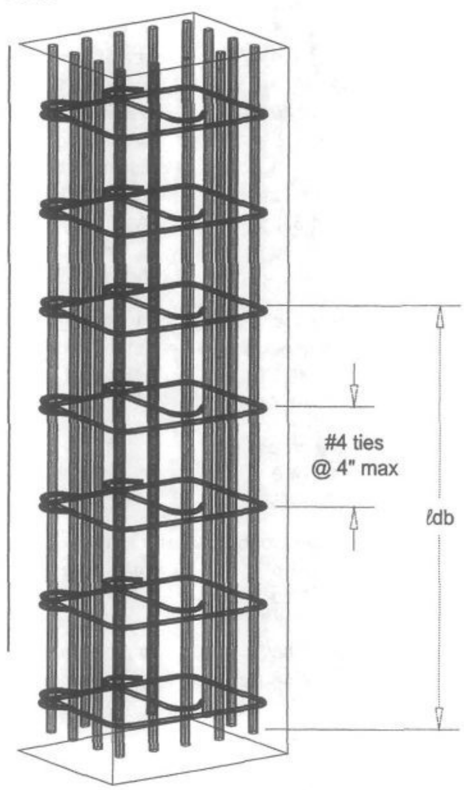
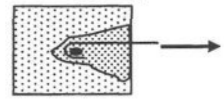


Figure 52-5 Compression reinforcement in a column.

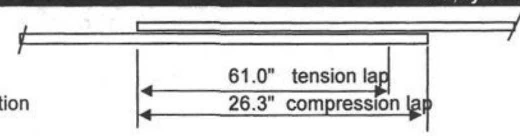
EMBED
TANK SUPPORT



A B C D E F G H I J K L M N

FLEXURAL REINFORCEMENT DEVELOPMENT — # 7, fy 60 ksi, f'c 4

M_n	**16.3**	k-ft/ ft	Unfactored moment capacity
$V_{u\ required}$	**6.5**	k_ult / ft	Required ultimate shear
d	**9**	in	depth of reinforcing
compressior	**0**	0/1 no	no / yes confinement by compressive reaction
$[V_n']$	**12**	k ult .	54% Provided shear capacity phi*Vn
%_cont	**0**	%	% of reinforcing after cutoff



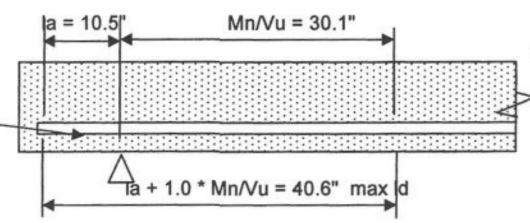
99 ACI 11.1.1 (11 - 1) input the value for FVn

Figure 52-6 Reinforcing lap distances.

FLEXURAL DEVELOPMENT at SUPPORTS and POINTS OF INFLECTION

l_a	*10.5*	*in*	*MAX(d, 12 * Bar_# / 8) at inflection point*	*length beyond point of inflection or*
$M_{n\_}$	16.33	k-ft	Unfactored moment capacity	embedment length beyond the center of the support
$V_{u\_}$	6.5	k ult	Required shear	
$[M_n/V_u]$	30.1	in	M_n / V_u * 12	
compression	1.00	unit	1+ comp * 0.30	0/1 no confinement by compressive reaction
$l_{d\ positive}$	40.6	in	compression * $[M_n / V_u] + l_a$	99 ACI 12.11.3 (12-2)
l_d'	31.3	in	$l_d <= l_{d\ positive}$	
	1	logic	OK	

The 1.3 factor is useable only when the reaction confines the end of the reinforcement

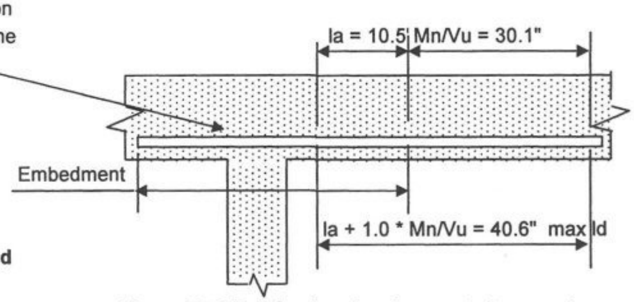


row 149

.Positive Moment Development 31.29 required < ld 31.29" provided

Figure 52-7 Reinforcing development at supports.

The 1.3 factor is useable only when the reaction confines the end of the reinforcement



.Positive Moment Development 31.29 required < ld 40.65" provided

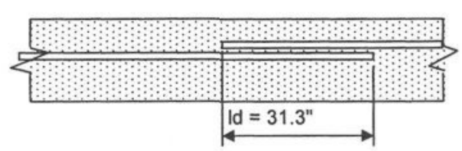
Figure 52-8 Reinforcing development at supports.

row 169

Flexural reinforcement terminated in a tension zone must satisfy:

Tension zone development / embedment used in rebar cut-off where reinforcing is not required to resist moment.

$[V_u/V_n]$	0.542 .		Required V_u/ (provided F V_n) <= 2/3
Cond_1	1	logic	99 ACI 12.10.5.1
Av_excess	0		99 ACI 12.10.5.2 not included here
#11_max	1	logic	#11 and smaller bars
% cont'	0	logic	% after cutoff >= 2*Mu required
$[V_u/V_n]'$	1	logic	Required_Vu / phi*Vn_allow <= 3/4
Cond_3	0	logic	$[V_u/V_n]$ * #11_max * %_cont'
tens_emb	1	logic	1 = tension zone embedment allowed for this configuration



row 179

Figure 52-9 Flexural reinforcing in a tension zone.

ACI 12.10.5.3

Vu / (phi * Vn) 54%
Mu_req'd / Mu_provided 0%
Condition 1, .. has been met
Tension embedment permitted
0

Tension embedment permitted
Condition 1, ..

row 189

A B C D E F G H I J K L M N

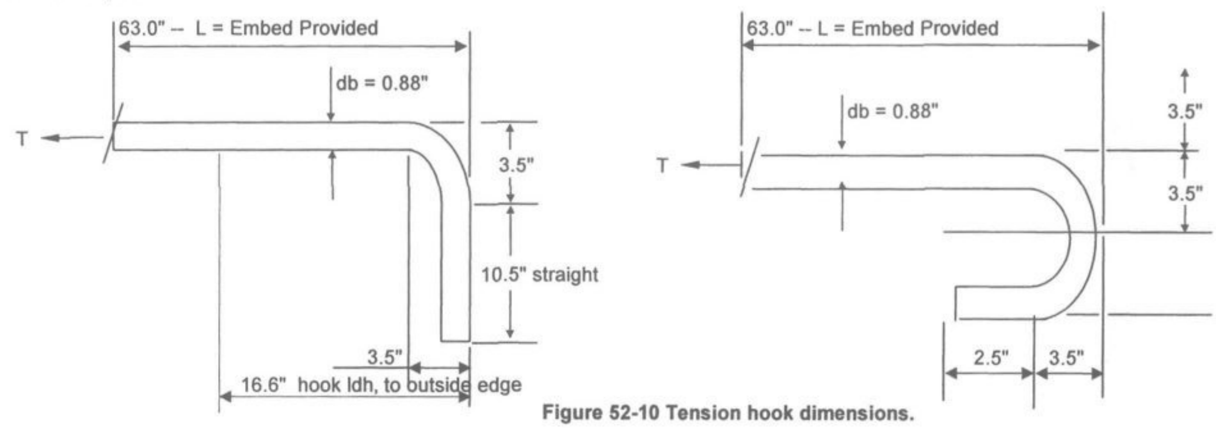
BAR DEVELOPMENT and HOOKS — # 7, fy 60 ksi, f'c 4

Bar_#	7	#	referenced from above	
f_y	60	ksi	rebar yield strength	
f'_c	4	ksi	concrete compressive strength	
A_s %	1	unit	0.00 - 1.00 $A_{s\ required}$ / $A_{s\ provided}$ = 100%	99 ACI 12.5.3.4
cover	3	in	concrete side cover	
cover_ext	3	in	concrete cover beyond end of bar or hook	
tie	0	0/1 no	no/yes ties -- see notes	
L	63	in	available space for embed or hook for flag	row 199

TENSION HOOK

l_{db}	31.3	in	Id_Table basic case	Hooks cannot be applied in compression 99 ACI 12.5.5
l_{dh_min}	7.0	in	MAX(bar_#, 6)	l_{hb} is the basic development length of a hook in tension.
l_{hb}	16.6	in	1200 * Bar_# / 8$\sqrt{f'_c}$ for f_y = 60 ksi	
f_y_factor	1.00	unit	f_y / 60000 99 ACI 12.5.3.1	l_{dh} is development length of a standard hook. This value must be the max of 8 bar diameters, 6", or
cover	2	in	concrete side cover	l_{hb} * (applicable modification factors).
cover_ext	2			Ties along ldh at 3*Bar_# /8 spacing ACI 12.5.4 row 209
cover'	1.00	unit	1 - (bar_#<=11) * (cover>=2.5) * (cover_ext>=2)*0.3	
tie'	1.00	unit	1 - (bar_#<=11) * (tie)*0.2	
A_s_%	1.00	unit	$A_{s\ required}$ / $A_{s\ provided}$	
l_{dh}	16.6	in	MAX($l_{dh\ min}$, l_{hb} * $f_{y\ factor}$ * cover * tie * A_s %')	
[l_{dh}<=L]	1	logic		
Area	0.60	in^2		
T	36.1	k	As_% & Area*F_y	Note: Iterate As_% to make tension hook
T_ult	32.5	k-ult	0.9*T	length equal to or less than length allowed. row 219

4db for #3 through #8 ≥ 2 1/2"
5db for #9, #10, #11
6db for #14, #18



row 229

Figure 52-10 Tension hook dimensions.

row 239

For ties, #3, #4, #5 inside bend diameter = 4 db
Tie hook extension = 6 db

. Tension hook 16.6 required < 63.0" allowed

row 249

A B C D E F G H I J K L M N

LAP SPLICE in TENSION — # 7, fy 60 ksi, f'c 4

Class A lap splice			
Factor	1.0	unit	
Lap	31.3	in	factor * l_d
	1	logic	

99 ACI 12.15.1
Use Class B splices, factor of 1.3 l_d, for:
Lap splices of deformed bars and deformed wire in tension.

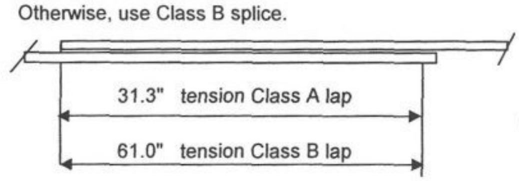
Except,
Class A splices, factor of 1.0 l_d, may be used when:
(1) the area of reinforcement provided is at least twice that required by analysis over the entire length of the splice and, row 259
(2) one half or less of the total reinforcement is spliced within the required lap length.

Otherwise, use Class B splice.

Class B lap splice			
Factor	1.3	unit	
Lap	61.0	in	factor * l_d
[Lap<=L]	1	logic	

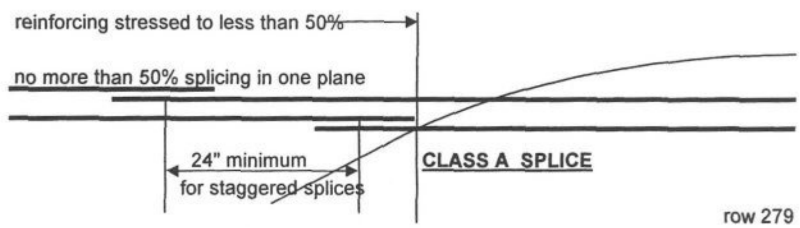
. **Tension Class A lap splice 31.3 required < 63.00" allowed**

. **Tension Class B lap splice 61.0 required < 63.00" allowed**



row 269

	As req / As provided 50%	100%
Up to 50% splicing	A	B
Greater than 50% splicing	B	B



row 279

Figure 52-11 Class A and B splices.

LAP SPLICE in COMPRESSION

[f'c<3]	1.00	unit	1 + (f'c<3) * 0.333
min_c1	26.3	unit	0.0005 * F_y * Bar_# /8
	1	logic	f_y <= 60 ksi
min_c2	26.3	unit	(0.0009 * F_y - 24) * Bar_#/8 for F_y > 60
	0	logic	f_y <= 60 ksi
Lap_c	26.25	in	
[Lap<=L]	1	logic	

99 ACI 12.16.1

Compression splices - ties throughout lap splice length with an effective area of 0.0015*(thickness of member)*(spacing of ties). row 289

. **Compression lap splice 26.25 required < 63.00" allowed**

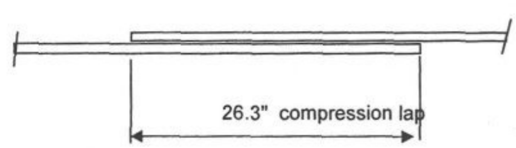


Figure 52-12 Lap splice in compression.

row 299

row 309

52 Embed.xls

A B C D E F G H I J K L M N

For BAR USED IN SHEAR FRICTION # 7, fy 60 ksi, f'c 4

Bar	6	unit	bar number 0.750" diameter		n UBC 1911.7.4.3
A_{vf}	0.44	in^2	area of bar in shear	1.4	monolithic concrete
f_y	36	ksi		1.0	concrete placed against roughened-hardened concrete
n	0.7	unit		0.6	against un-roughened hardened concrete
l	1	unit		0.7	against as-rolled structural steel
u	0.7	unit	n*lambda = u		

lambda UBC 1911.7.4.3
1 normal weight concrete — row 319
0.85 sand light weight concrete
0.75 all-light weight concrete

V_n	11.088	k	A_{vf} * F_y * n * l
V_u_shear	9.425	k-ult	0.85*V_n allowable (11-26)

For net tension across shear plane,
add As_tension + As_shear friction

UBC 1911.1.1

T_u_tension	14.256	k-ult	0.9* f_y * A_bar allowable
T_tension	0.5	k	required tension
V_shear	3.32	k	required shear
factor	1.43		1.43E
T_u_required	0.715	k-ult	
V_u_required	4.748	k-ult	

row 329

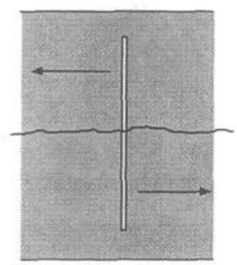


Figure 52-13 The shear friction plane.

T_u_req'd / T_u_tension	+ V_u_req'd / V_u_shear	Unity
0.715 / 14.256	4.748 / 9.425	
0.050	0.504	0.554 Unity.

row 339

PHOTOGRAPH

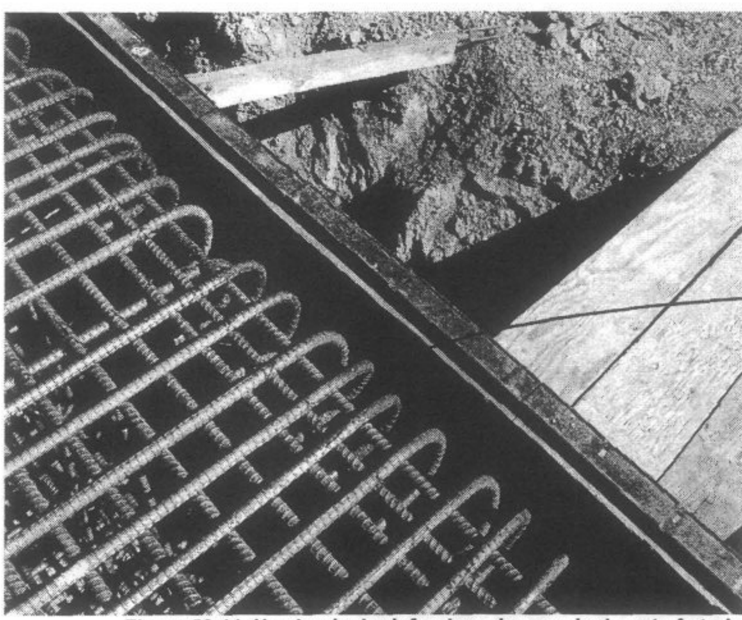


Figure 52-14 Use hooked reinforcing where embedment of straight bars cannot be achieved in the space provided.

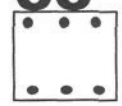
Because this is a pile cap, there are no vertical bars at the face. Vertical bars are usually used to limit unsightly cracks (temperature reinforcing). The appearance of cracks won't affect this buried face. row 349

Hooked reinforcing

The straight bar running through the hook provides "confinement." More concrete than just that used by the hook is added by the perpendicular bar.

row 359

REINFORCED CONCRETE BEAM
TANK SUPPORT



Values from frame analysis for water test greatest moment
24" piling, 42" Deck, 48" Pile Cap

CONCRETE BEAM DESIGN — I gross 575,967 in^4 / I cracked 123,858 in^4 / I effective 575,967 in^4

f_y	**60** ksi		yield strength of reinforcing
f'_c	**4** ksi		compessive strength of concrete
d'	**5** in		depth of compression reinforcing
b_w	**84** in		width
d	**40.0** in		depth of tension reinforcing
depth_OA	**42** in		overall depth
	Bar Qty	Bar Size#	A_s
A'_s	**22.00**	**7**	13.20 in^2
A_s	**22.00**	**7**	13.20 in^2
M working	**936.0** k-ft		required service level moment
M_u req'd	**1341.0** k-ft ult		required ultimate/factored moment

M_U prov 2964.67 k-ft ultimate provided
OK Beam stressed to 45 %
OK As min 11.20 < As provided 13.20
OK x balance 14.87 ≥ 4.264 required

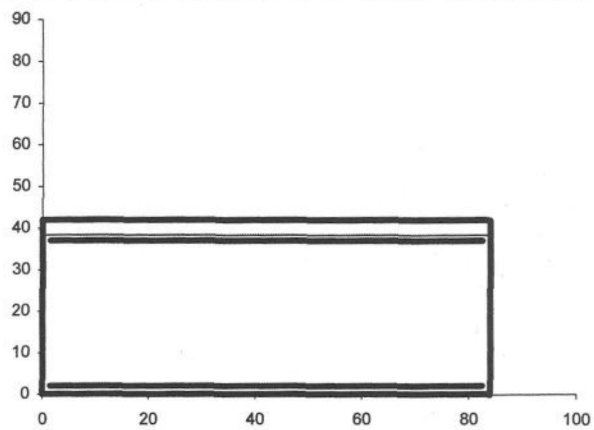


Figure 53-1 Beam cross-section with Whitney's stress block and reinforcing. row 30

Length	**39** ft	length of joist
t	**4.5** in	thickness of slab
c	**78** in	spacing of joists
flange	**0** logic	0 = no flanges, 1 = spandrel, 2 = T beam

Bar Size # in American nomenclature, bar size is given as a number which equates to 8 th's of an inch hence, a #6 bar is 6/8 inch = 3/4"

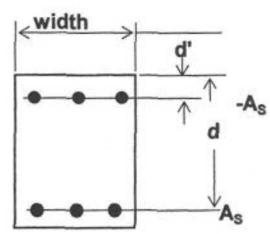
f_y ultimate tensile strength of reinforcing, k/in^2
f'_c ultimate compression strength of concrete, k/in^2

I_g	575967 in^4	
$I_{cracked}$	123858 in^4	
I_e	575967 in^4	
ε_t	0.00507 unitless	allowable tension reinforcing strain
		0.00400 minimum strain allowed

row 40

ρ_{min} -- Minimum Reinforcement in Flexural Members

A_s min $_1$	10.63 in^2	$3\ \sqrt{f'_C}\ /f_y\ b_w\ d$ 02 ACI 10.5.1 (10-3)
		3 * √ 4 *1000 * 84.0 * 40.0 /60 /1000
A_s min $_2$	11.20 in^2	200 * w * d /f_y /1000 02 ACI 10.5.1
		200 * 84.0 * 40.0 /60 /1000
A_s logic	1 logic	MAX(11.20, 10.63) ≤ 13.20



row 50

Figure 53-2 Beam cross-section.

When the area of tension reinforcing steel is less than **$+A_s$** minimum, the amount of reinforcing provided must be increased by 1/3 beyond that needed for tensile reinforcement. 02 ACI 10.5.3

When the beam is stressed to 75% and
$+A_s$ = 1.33 x A_s *provided, the minimum requirements of* reinforcement have been met.

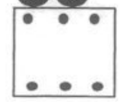
row 60

$-A_s$, A'_s *negative reinforcing - usually the top steel,* in^2
$+A_s$ positive reinforcing - usually the bottom steel, in^2

For Seismic Resistance

A_s min	11.20 in^2	200 * b_w * d / f_y ACI 21.3.2
		200 * 84 * 40.0 /60 /1000

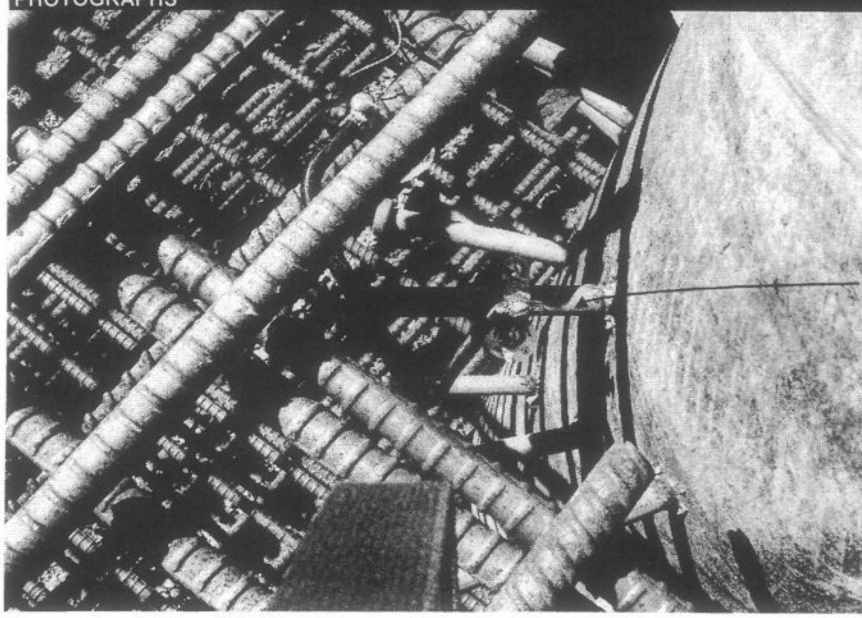
row 70



Values from frame analysis for water test greatest moment
24" piling, 42" Deck, 48" Pile Cap

A B C D E F G H I J K L M N

PHOTOGRAPHS



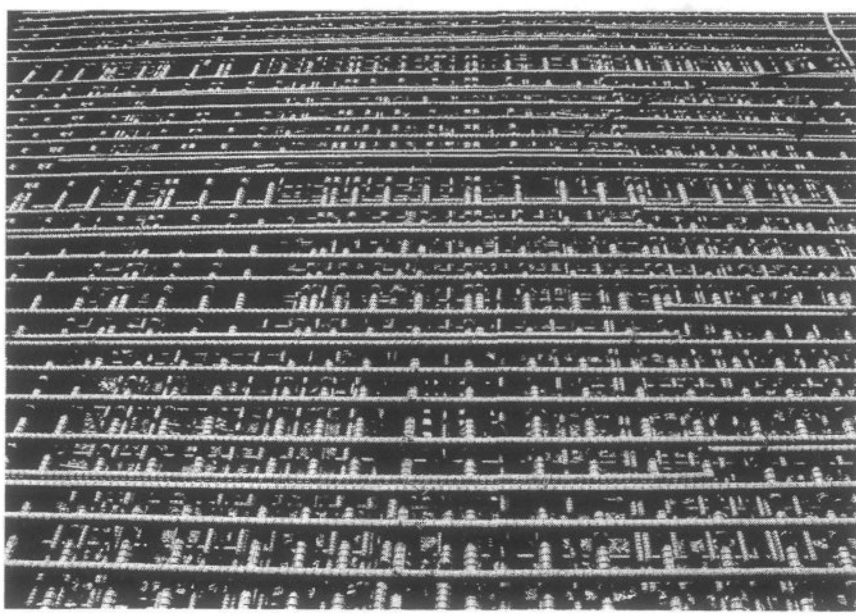
row 80

Positive gounding of the reinforcing mat to the pile column.

row 90

Figure 53-3 Looking down at a forrest of rebar and studs.

row 97



Splicing

Splicing adds to the congestion. 1" spacing is generally required to allow the 3/4" aggregate to pass down through the upper and lower mats.

This mat is made up of #7's @ 4" each way. Because the cross-section of reinforcing bar is oblong and with lugs, about 1" to 1 1/8" of space is required to accomodate the bar.

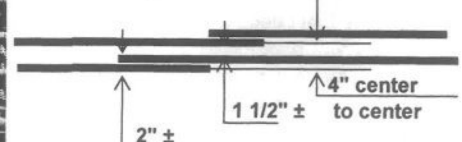


Figure 53-4 #7's @ 4."
For some serious reinforcing, try #8's @ 4."

The contractor did specify a specialized mix to make sure that the concrete would place easily.

LN_2 BULK STORAGE TANK TEST MEASUREMENTS

Christy
November 5, 2003

54 Tank Test Measurements.xls

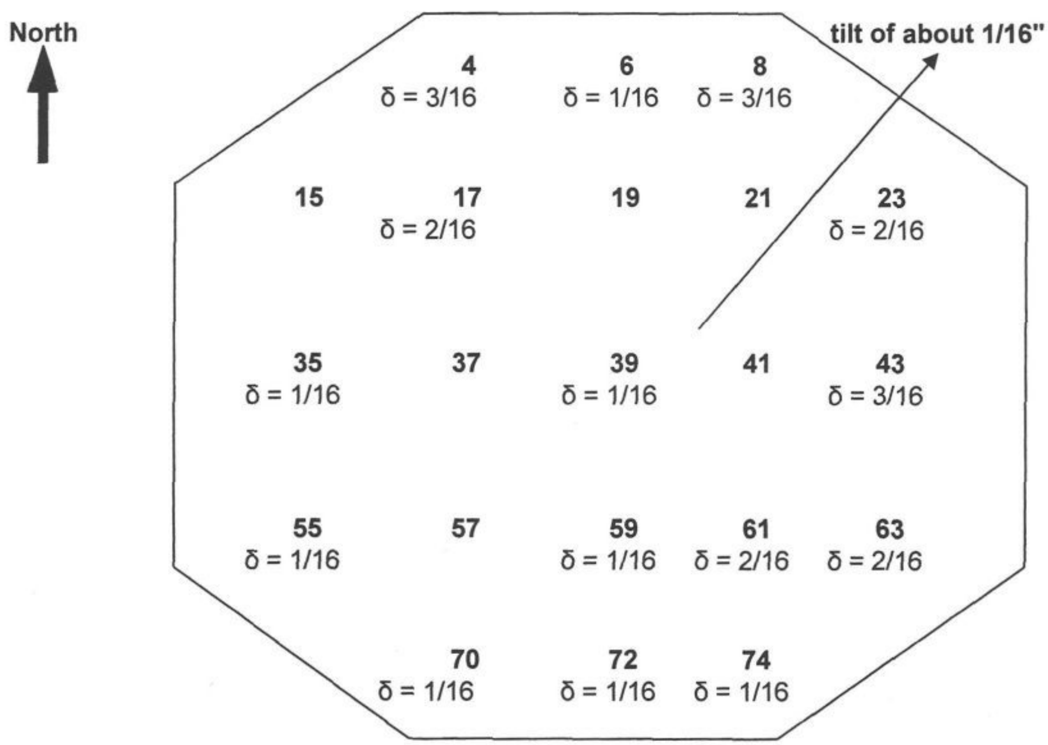
Summary of Tank Test Measurements

Please refer to the D sized drawing for measurement recordings.

The soils engineer predicted less than **1/4"** settlement under working loads for individual piles. It appears that our greatest settlement is on the order of **1/8"**.

Targets were glued to foundation columns on Friday, October 24, 2003. The water fill process began on Thursday the 29th and was finished on Sunday, November 2nd.

row 20



row 30

row 40

Figure 54-1. Laser Level Measurements of Column Settlements

row 50

THE LASER LEVEL SETUP

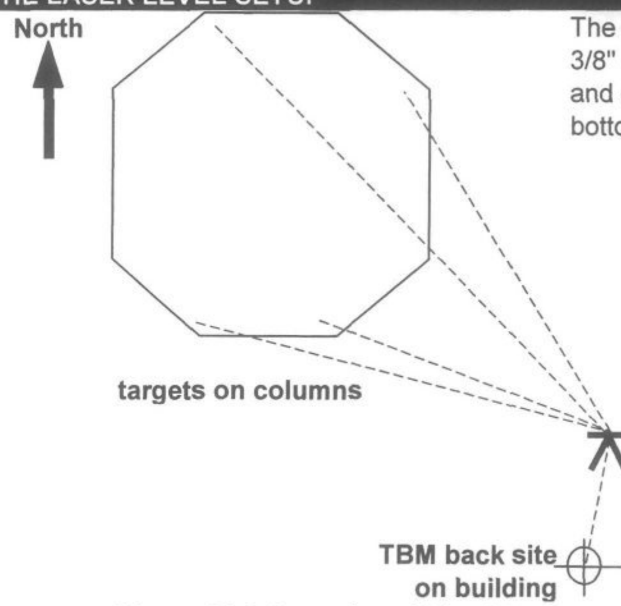
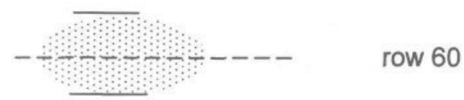
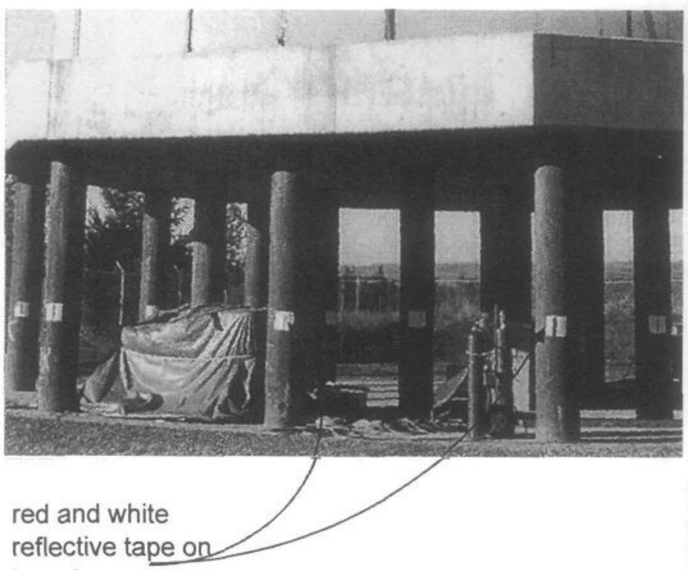


Figure 54-2 Laser Level Plan View

The laser level dot is about 1/8" at 80 ft and 3/8" at 130 ft. The dot can be split in half by eye and can also be split by marking the top and bottom of the dot and calculating the middle.





red and white reflective tape on targets

Figure 54-3 Enlargement of Targets on Columns

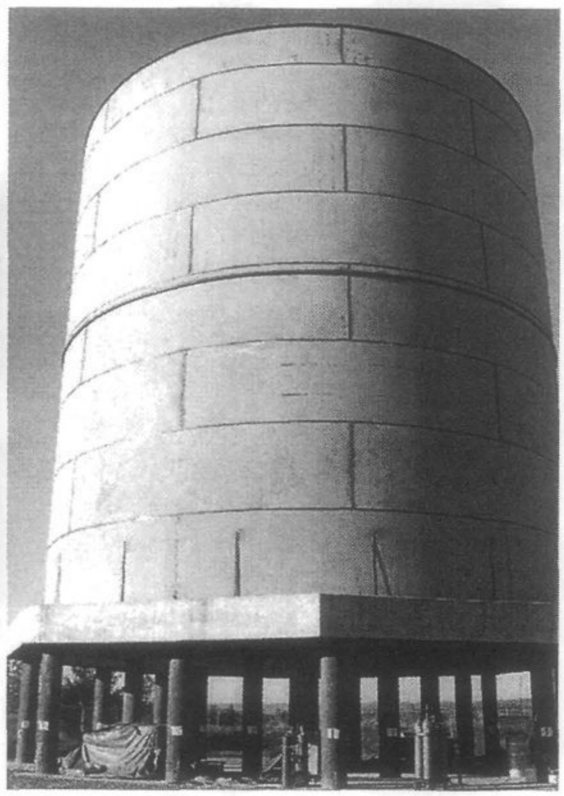


Figure 54-4 Tank Elevation Looking Northwest

COLUMN SHORTENING

5 and **3 Lb**. lead weights were hung on monel line from the bottom of the deck.

monel 0.000778 /100° F /100 ft coefficient of expansion
Temperatures varied from 43° F on Sunday to 57° F on Monday and

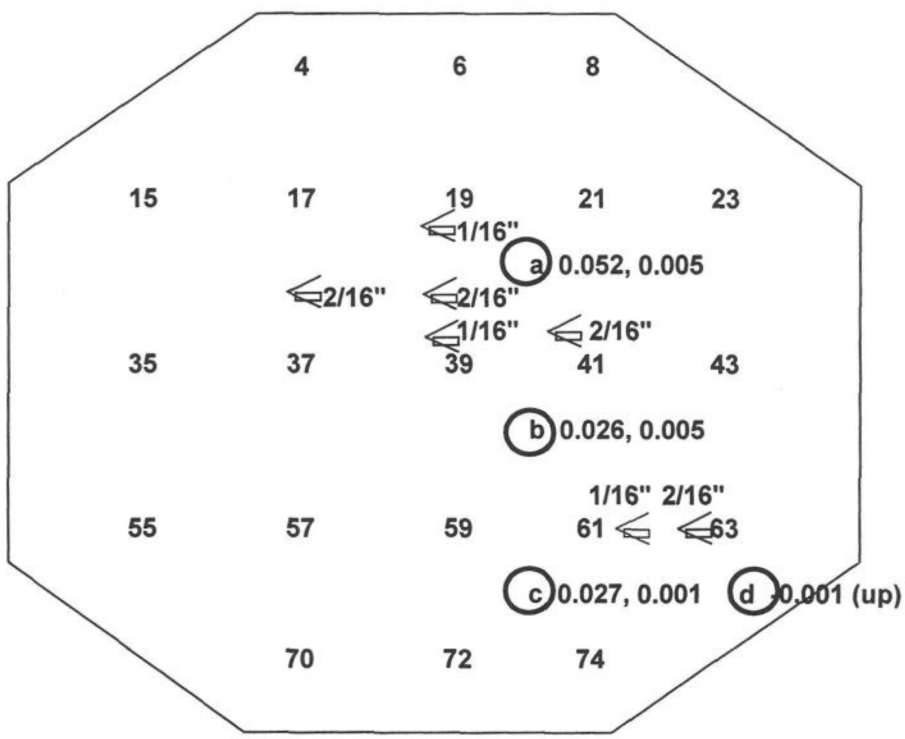
row 100

results in about a 132" /1200 * 14° F * 0.000778 in/in = 0.0012" of lengthening.
Temperature lengthening is a nominal issue in these measurements.

○ **3** mechanical dial gages during the water loading test.
The electronic dial gage was used only on the day of the air overpressure test.

< laser tape measure from pile cap to deck underside

row 110



row 120

row 130

Figure 54-5 Dial Gage Telltales and Laser Measurements

Note: The < symbol indicates a **<** painted on the concrete and the laser's position on that **<**. Laser measurements were made with a **Hilti PD25**.

COLUMN SHORTENING -- Continued

For reference: 1/16" = 0.0625"

0.007" calculated deflection down

shortening say 0.026 - 0.007 - 0.0035 = **0.016"**

0.0035" estimated deflection up

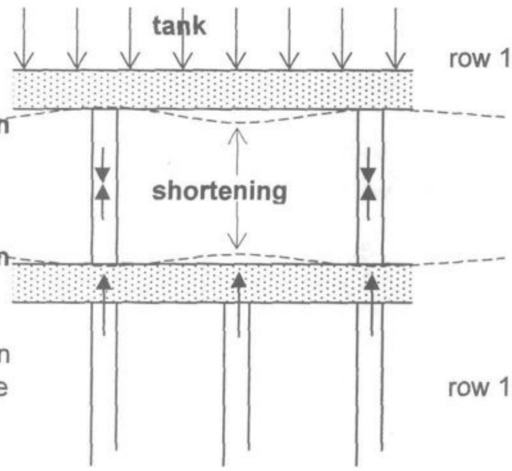


Figure 54-6 Foundation Partial Elevation

Estimate (measured) column load(s) from telltale information
Convert column reinforcing to an equivalent area of concrete
and add to the gross area of the column.

A_s	52.96	in^2	
$A_{concrete}$	399	in^2	
n	8.04	unitless	
$A_{effective}$	825	in^2	8.04 * 52.96 + 399

For stress in the column(s)
$E\,\varepsilon = \sigma$

138" line length

E	3605	k/in^2	
ε	1.159E-04	in/in	0.016 in /138 in
σ	0.418	k/in^2	3605 k/in^2 * 1.159E-04
$P_{measured}$	**345**	**k**	0.418 k/in^2 * 825 in^2

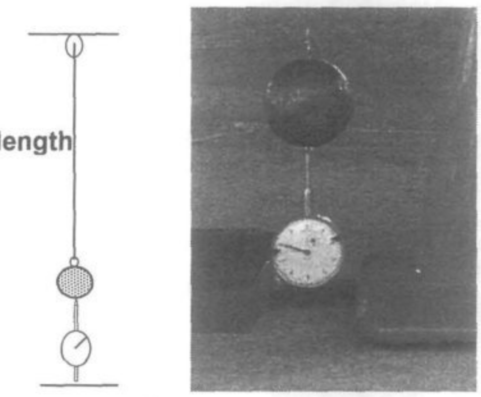


Figure 54-7. Mechanical Dial Gage Telltale with 5-pound Lead Weight

The average design values for columns 39 to 139 and 41 to141 is **470k**.

Tank	741	k	empty weight
Deck	1839	k	concrete deck weight
$P_{DL\ Avg}$	123	k /column	(741 + 1839) /21 columns
$P_{calculated}$	**347**	**k**	470 - 123

E	concrete modulus of elasticity	
ε	strain	row 170
σ	stress	
P	force	

The $P_{measured}$ value of **345 k** compares favorably with $P_{calculated}$ water test weight of **345 k.**

LN_2 BULK STORAGE TANK TEST MEASUREMENTS

COLUMN SHORTENING -- Continued

For deflections during the 3.75 psi overpressure

Calculate the change in column force using the change in the distance between the bottom of the deck and the top of the pile cap.

δ	0.005 in	measured during the test
ε	3.62E-05 in/in	0.005/138
σ	0.130616 k/in^2	3.62E-05 * 3605
$P_{measured}$	**108 k**	0.130616 k/in^2 * 825 in^2
$P_{calculated}$	**106 k**	0.00375 k/in^2 *144 in^2/ft^2 * 14ft * 14ft

54-8 Electronic Dial Gage Telltale with 3-Pound Lead Weight

The $P_{measured}$ of **108 k** compares favorably to the $P_{calculated}$ of **106 k**.

Note that electronic dial gage d indicates **-0.001"** (up). This amounts to about **22k** reduction in force in column force because the shell and anchor bolts of the inner tank are pulling up against the deck.

The mechanical dial gage c indicates **+0.001"** (down) is also in keeping with the inner tank shell uplift. row 200

The foundation appears to have performed as designed.

Sincerely,

Craig T. Christy, P.E.

row 210

CONSULTING COMPANY **NOTES**

ENGINEERING with the SPREADSHEET

A	B	C	D	E	F	G	H	I	J	K	L	M	N

20

30

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PART 5:

REFERENCE MATERIALS

CONSULTING COMPANY

NOTES

ENGINEERING with the SPREADSHEET

A	B	C	D	E	F	G	H	I	J	K	L	M	N

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CONSULTING COMPANY

LRFD COMPARED TO WORKING STRENGTH LOADS

INTRODUCTION

55

LRFD

Christy
15:41
12/20/05

Not included on the CD-ROM

ENGINEERING with the SPREADSHEET

55 LRFD Introduction.xls

A B C D E F G H I J K L M N

ALLOWABLE STRESS DESIGN versus LOAD RESISTANCE FACTOR DESIGN

Following these comments are examples for a liquid nitrogen tank in a zone 4 environment. The examples compare LRFD factoring on the left side of the page versus working strength design on the right side of the page.

For trapezoidal loading where all of the soil below the footing is loaded in compression, the ratio of LRFD to working strength is 1.41. However, where working strength calculations show +0.015 ksf, LRFD calculations show -0.053 ksf which should not be ignored.

In the example on the next page, the footing size has been decreased to take advantage of the soil's load bearing capacity and a triangular loading where some of the footing does not bear on the soil. The working strength triangular calculations indicate 1.860 ksf of bearing during the event while the LRFD calculations show 5.150 ksf in ultimate bearing which is unrealistic.

When load factoring first appeared about 25 years ago, it was declared as "the way" to save on concrete reinforcing. At the time the codes were re-written to take "advantage" of load factoring, reinforcing for shear was substantially increased because of the many failures that had occurred.

In truth, the savings in tension reinforcing was due to the Whitney's stress block which reflected the way in which real-life concrete behaves. The savings are not due to load factoring.

There are actually two issues in the debate over LRFD:

1. Factoring loads for a better probabilistic estimate of load risk
2. Better methods of calculating beams, columns, footings, and etcetera.

The same issues apply to LRFD steel design. In Section 2 of the AMERICAN INSTITUTE of STEEL CONSTUCTION's ASD manual, "Allowable Moments in Beams" graphs show an arbitrary drop from 24 ksi to 21.6 ksi in most beams which often effects a beam over a substantial portion of its length. This drop is equal to a 9% reduction in stress and is simply an issue of how beams are modeled in our calculations. Smooth this drop into a curve and you may possibly save on steel just as the Whitney's stress block saves tension reinforcing in concrete.

LRFD may reflect a more accurate estimate of load risk but it is an estimate that does not vary much from the straight forward estimates. In building missiles, 5% counts for a lot but, in civil and structural engineering, the safety factor for beams and columns starts at about 1.9 and the safety factor for connections is usually taken as 4 or 5.

LRFD adds complication to an uncertain world. It takes away your ability to estimate a design in your head which is important both in the field and when using a computer. And, as can be seen in the following examples, it leads us to bogus answers in our more complicated calculations.

We have known for decades that a residential bedroom floor should be designed for a 40 psf live load and a live load deflection not to exceed L/360. Usually, for quality construction, we increase the joist size to the next size up for greater comfort. When designing cold formed steel joists, limit live load deflection to L/500 for comfort -- all of the load factoring in the world will not make up for an irate owner who has a bouncy floor.

ALLOWABLE STRESS DESIGN versus LOAD RESISTANCE FACTOR DESIGN -- Continued

The old ASD loads have the required factors built-in -- in wood design, be careful to check deflection on longer spans.

When you use LRFD, check deflection, drift, and vibration for all materials.

The following examples yield these results:

ITEM	LRFD Factor / unfactored loads	
floors	1.59	
foundation DL + LL	1.44	
Foundation trapezoidal	~~1.41~~ e_x calculated LRFD	row 70
	1.29 e_x calculated unfactored loads	
Foundation triangular	~~3.18~~ e_x calculated LRFD	
	1.27 e_x calculated unfactored loads	
Average factor	1.40	

row 90

row 100

LRFD COMPARED TO WORKING STRENGTH LOADS

A B C D E F G H I J K L M N

LOAD FACTOR RESISTANCE DESIGN

The first factoring example compares four common load configurations for residential and storage floors. In using an average factor of 1.59, the result was from 5% heavier to 5% lighter than what the LRFD factoring would yield.

factor **1.59** generic factor ultimate load / working load

	lb/ft^2		factor	load	ratio			
LL	**40**	residence	1.7	68.0				row 20
DL	**15**	wood framing	1.4	21.0	1.62	-1.77 %		
LL	**125**	storage	1.7	212.5				
DL	**15**	wood framing	1.4	21.0	1.67	-4.90 %	5% unconservative	
LL	**40**	residence	1.7	68.0				
DL	**75**	concrete	1.4	105.0	1.50	5.39 %	5% conservative	
LL	**125**	storage	1.7	212.5				
DL	**75**	concrete	1.4	105.0	1.59	0.16 %		row 30
				average ratio	1.59			

Note:
ft^4 is the same as ft^4. Using the carrot ^ is a notation shortcut and reflects the way an exponent is written in spreadsheets.

row 40

row 50

row 60

A B C D E F G H I J K L M N

FOUNDATION IN OVERTURNING -- TRAPEZOIDAL LOADING

The following examples are used to demonstrate the design of footings to resist seismic loads -- these footings are considered to be eccentric footings.

The issue is: can we mix LRFD with eccentricities derived from the working loads to get reasonable ultimate moment values with which to design concrete? Using factored loads to derive the eccentricity of a footing can yield very unreasonable results.

Length	**29**	ft	length along the X axis	
Width	**29**	ft	width along the Y axis	row 70
Ixx	58940	ft^4	moment of inertia of footing area about YY	
Area	841	ft^2	area of footing	
Depth	**1.5**	ft	depth (thickness) of footing	
DL_ftg	189.2	k	weight of footing at 0.150 k/ft^2	
Height	**33.17**	ft	height of tank	
DL_v	**33**	k	tare (empty) weight of tank	
LL_c	**39.81**	k	contents of tank	row 80
DL_surr	222	k	vessel + footing	
LL_sum	33	k	contents	
DL_M	3222	k-ft	dead load -- max DL righting moment	
LL_M	479	k-ft	live load -- max LL righting moment used in seismic	
Mot_W	**106.79**	k-ft	wind overturning to bottom of slab for ultimate strength	row 90
Zone	0.4		seismic zone factor	
soil	0.44		stiff soil	
Na	1.5		near source factor	
R	2.2		structure response factor	
I	1.25		importance factor structure at grade -- oxygen	
Seismic	**0.938**	g ult	Factor used in ultimate strength seismic calculations equation (30-5)	

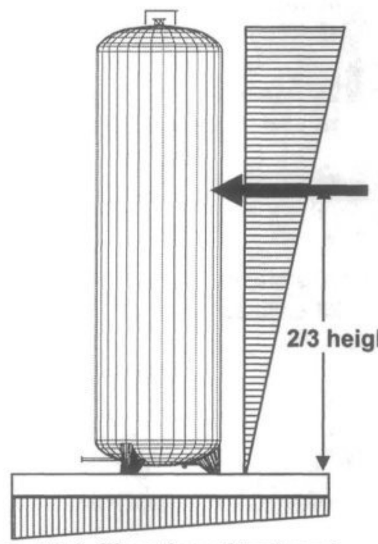


Figure 56-1 Elevation of tank and foundation in overturning.

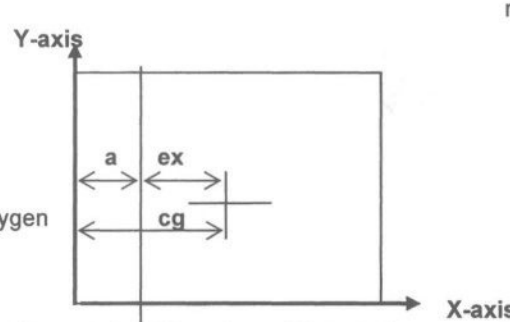


Figure 56-2 Plan view of foundation.

Mot_E 1643 k-ft ult seismic overturning to bottom of slab for ultimate strength
(Depth /2 * DL_ftg + Height * 2/3 * (DL_v + LL_c)) * Seismic
1.50ft / 2 * 189.2k + 33.17ft * 2/3 * (33.00k + 39.81k) * 0.938 g

M_ult 5325 k-ft ult 1.4 D + 1.7 L righting moment
1.4 * 3,222 + 1.7 * 479

M_work 3701 k-ft DL + LL righting moment
1.44 ratio q ultimate / q working

row 110

FOUNDATION IN OVERTURNING -- TRAPEZOIDAL LOADING -- Continued

Ultimate load at loaded edge

1.1 * (1.2D + 1.0E + (f_1 LL_ + f_2 S))
'97UBC 1612.2.1 12-5a

Mot_E 1808 k-ft ult 1.1 * 1,643
MrtD+L 4780 k-ft ult 1.1 * (1.2 * 3,222 + 479)

a 9.02 ft (Mrt_D_L - Mot_E) /(1.1 * 1.2 * DL_sum + 1.1 * LL_sum)
(4,780 - 1,808) /(1.1 * 1.2 * 222 + 1.1 * 33) row 120

cg_x 14.50 ft 29.00 /2 from loaded edge along x
ex 5.48 ft ult (14.50 - 9.02) CG - a LRFD loads

P DL&LL /A +/- P * ex * cx /Ixx +/- P * ey* cy /Iyy = sum
0.000 0.392 + 0.445 + 0.000
1.1 * (1.2 * 222 + 33) * 5.48 * 14.50 /58,940
1.1 * (1.2 * 222 + 33) /841

0.392	+	0.445	+	0.000	=	0.837 ksf ult		row 130
0.392	-	-0.445	+	0.000	=	-0.053 ksf ult		
							negative loading not possible	

ALTERNATIVELY -- Use ex calculated with unfactored DL + LL

Mot_E 1174 k-ft M_ot ult / 1.4
MrtD&L 3701 k-ft Mrt_D&L rotation about XX

a 9.90 ft (Mrt_D_L - Mot_E) /(DL_sum + LL_sum) row 140
(3,701 - 1,174) /(222 + 33)

cg_x 14.50 ft from loaded edge along x
ex 4.60 ft CG - a

P DL&LL /A +/- P * ex * cx /Ixx +/- P * ey* cy /Iyy = sum
0.000
1.1 * (1.2 * 222 + 33) * 4.60 * 14.50 /58,940 0.392 + 0.373 + 0.000
1.1 * (1.2 * 222 + 33) /841

0.392	+	0.373	+	0.000	=	0.765 ksf ult	row 150
0.392	-	-0.373	+	0.000	=	0.019 ksf ult	

row 160

A B C D E F G H I J K L M N

FOUNDATION IN OVERTURNING -- TRAPEZOIDAL LOADING -- Continued

Working load at loaded edge

Mot_E	1174	k-ft	M_ot ult / 1.4
MrtD&L	3701	k-ft	Mrt_D&L rotation about XX
a	9.90	ft	(Mrt_D_L - Mot_E) /(DL_sum + LL_sum)
			(3,701 - 1,174) /(222 + 33)
cg_x	14.50	ft	from loaded edge along x
ex	4.60	ft	CG - a

row 170

P DL&LL /A	+/-	P * ex * cx /Ixx	+/-	P * ey* cy /Iyy	=	sum	
				0.000		0.303 + 0.289 + 0.000	
		(222 + 33) * 4.60 * 14.50 /58,940					
(222 + 33) /841							
0.303	+	0.289	+	0.000	=	0.592	ksf asd
0.303	-	-0.289	+	0.000	=	0.015	ksf asd

row 180

0.837 /0.592	=	**1.41 ratio**	q ultimate / q working
0.765 /0.592	=	**1.29 ratio**	q ultimate / q working

row 190

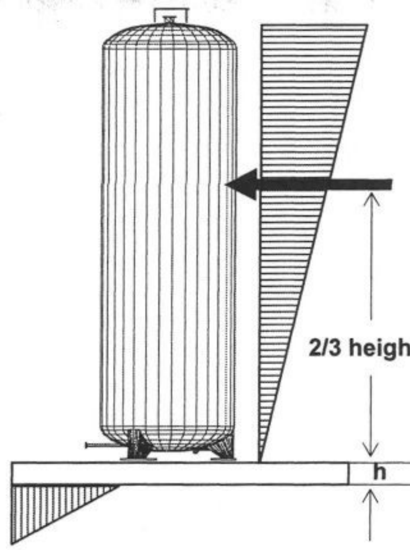
row 200

row 210

A B C D E F G H I J K L M N

FOUNDATION IN OVERTURNING -- TRIANGULAR SOIL LOADING

Length.	**20.00**	ft	length along the X axis
Width.	**20.00**	ft	width along the Y axis
Ixx.	13333	ft^4	moment of inertia of footing area about YY
Area.	400	ft^2	area of footing
Depth.	**1.5**	ft	depth (thickness) of footing
DL_ftg.	90.0	k	weight of footing at 0.150 k/ft^2
Height.	**33.17**	ft	height of tank
DL_v.	**33**	k	tare (empty) weight of tank
LL_c.	**39.81**	k	contents of tank
DL_sum	123	k	vessel + footing
LL_sum	33	k	contents
DL_M.	1230	k-ft	dead load -- max DL righting moment
LL_M.	330	k-ft	live load -- max LL righting moment used in seismic
Mot_W.	**106.79**	k-ft	wind overturning to bottom of slab for ultimate strength



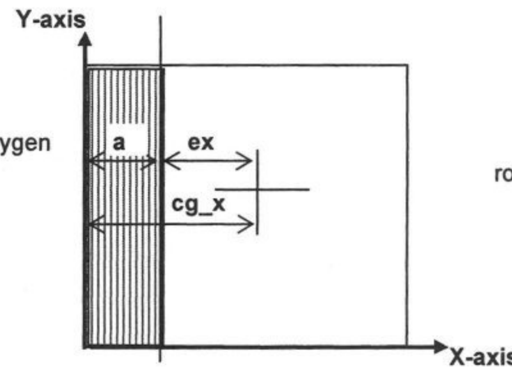
row 220

row 230

Figure 56-3 Elevation of tank and foundation in overturning.

Seismic

Zone	0.4	zone factor
soil	0.44	stiff soil
Na	1.50	near source factor
R	2.2	structure response factor
I	1.25	importance factor structure at grade -- oxygen
Seismic	**0.938** g ult	Factor used in ultimate strength seismic calculations equation (30-5)



row 240

Figure 56-4 Plan view of foundation.

Mot_E 1574 k-ft seismic overturning to bottom of slab for ultimate strength
(Depth /2 * DL_ftg + Height * 2/3 * (DL_v + LL_c)) * Seismic
1.50ft / 2 * 90.0k + 33.17ft * 2/3 * (33.00k + 39.81k) * 0.938 g

row 250

row 260

FOUNDATION IN OVERTURNING -- TRIANGULAR SOIL LOADING -- Continued

q = 2 * P /(3 * width * (B cross section of footing /2 - e))

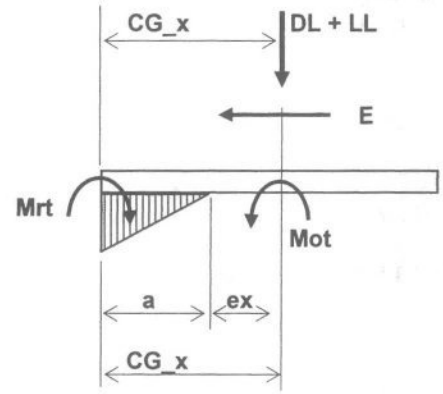


Figure 56-5 Elevation view of triangular soil loading.

Ultimate Loads
1.1 * (1.2D + 1.0E + (f_1 LL_ + f_2 S))
'97UBC 1612.2.1 12-5a

Mot_E	1731	k-ft_ult	1.1 * 1,643 k-ft_ult
Mrt	1987	k-ft_ult	1.1 * (1.2 * 1,230 + 330)
DL + LL	199	k_ult	1.1 * (1.2 * 123 + 33) k_ult
ex	8.71	ft_ult	20.00 /2 - (1,987-1,731) / 199
q_x ult	5.145	ksf_ult	2*198.66 / (3*20.00*(20.00 /2-8.71)
a	3.86	ft	

Safety factor in seismic overturning = 1.39 > 1.00 required

Working load at loaded edge row 280
q about yy = 3 * EDGE_Y * (EDGE_X/2 - e) where
e = CG_x - (M_rt - M_ot) / SUM (LL + DL)

Mot_E	1124	k-ft	M_ot ult / 1.4
Mrt	1560	k-ft	
DL + LL	156	k	
ex	7.20	ft	20.00 / 2 - (1,560 - 1,124) / 156
q_x asd	1.860	ksf asd	2*156.00 / (3*20.00*(2C
a	8.39	ft	

row 290

5.145 /1.860 = 2.77 ratio q ultimate / q working

ALTERNATIVELY -- Use ex calculated with unfactored DL + LL

row 300

DL + LL	199	k_ult	
ex	7.20	ft	20.00 / 2 - (1,560 - 1,124) / 156
q_x	2.369	ksf_ult	2*198.66 / (3*20.00*(20.00 /2-7.20)
a	8.39	ft	

2.369 /1.860 = 1.27 ratio q ultimate / q working

row 310

LRFD COMPARED TO WORKING STRENGTH LOADS

A	B	C	D	E	F	G	H	I	J	K	L	M	N

LRFD FACTORING '97 UBC

1612.2.1 Basic load combinations with exception 2 -- multiply loads by 1.1 for loads including seismic forces

D	0.0	dead load -- max DL righting moment	
L	0	live load or earth pressure -- max LL righting moment used in seismic	
L_r	0	roof live load	
S	0	snow	
W	0	wind	
E	70.0	seismic -- when derived from the UBC, use E/1.4 for working (service level) values	
T	0	differential settlement	
H	0	earth pressure	row 320
F	0	fluid pressure, load factor = 1.4	
max	70.0		
f 1	1.0	1.0 floors in public assembly, LL >100 psf, garage 0.5 of other live loads	
f 2	0.2	0.7 roofs that can't shed snow, 0.2 other	

97 UBC 1612.2.1

E_	1.1	multiplie use 1.1 for concrete and masonry subjected to seismic forces		
12-1	0	1.1 * (1.4 D + 1.3F)	1.54D + 1.43F	
12-2	0	1.1 * (1.2D + 1.6*L +0.5* (L or S))		row 330
12-3	0	1.1 * (1.2D + 1.6(Lr or S) + (f_1 L or 0.8W))		
12-4	0	1.1 * (1.2D + 1.3W +f_1 L + 0.5(Lr or S))		
12-5a	77	1.1 * (1.2D + 1.0E + (f_1 LL_ + f_2 S) + 1.3F)		
			1.32 D + 1.1 E + 1.1 (f_1 L or 0.88 W) + 1.43F	
12-6a	77	1.1 * (0.9D + 1.0E or 1.3W)	0.99 D + 1.1 E or 1.43 W	
12-6b	-77	1.1 * (0.9D - 1.0E or 1.3W)	0.99 D - 1.1 E or 1.43 W	
max	77	ratio 1.100		
				row 340

97 UBC 1909.2 for Concrete

		Where E is included in the design, use UBC 1612.2.1 per UBC 1909.2.3		
9-1	0	1.4D + 1.7L + 1.4F		
9-2a	0	0.75 (1.4D + 1.7L + 1.7W)	1.05 D + 1.275 L + 1.275 W	
9-3a	0	0.9D + 1.3W		
9-4a	0	1.4D + 1.7L + 1.7H		
9-4b	0	0.9D + 0L + 1.7H		row 350
9-5	0	0.75 (1.4D + 1.4T + 1.7L + 1.4F)	1.05 D + 1.05 L + 1.275 L + 1.05 F	
9-6	0	1.4 (D + T)	1.4 D + 1.4 T	
max	0	ratio 0.000		
				row 360

LRFD FACTORING '99 ACI

99 ACI Values		Where E = UBC seismic value / 1.4		
E UBC	50	UBC E / 1.4		
9-1a	0	1.4 D + 1.7 L		
9-1b	0	1.4 D + 1.7 L + 1.4 F		
9-2a	0	1.2 D + 1.6 L + 1.7 W		
9-2b	70	1.05 D + 1.28 L + 1.4 E		
9-3a	72	0.9 D + 1.43 E		
9-3b	0	0.9 D + 1.7 H		row 370
9-4a	0	1.4 D + 1.7 L + 1.7 H		
9-4b	0	0.9 D + 1.7 H		
9-5	0	1.05 D + 1.4 T + 1.275 L		
9-6	0	1.4 D + 1.4 T		
max	72	ratio	1.021	

row 380

row 390

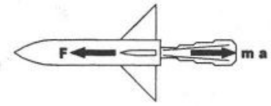
row 400

row 410

ACCELERATION

57

Christy
18:40
12/20/05



57 Acceleration.xls

A	B	C	D	E	F	G	H

INTRODUCTION

This is part of a demonstration for students at Robert Gray Middle School, Portland, Oregon.

x	distance	feet			quantity
t	time	seconds			quantity
v	velocity (speed)	$\frac{dx}{dt}$	$\frac{\text{change in distance}}{\text{change in time}}$	$\frac{\text{feet}}{\text{second}}$	steady state
a	acceleration	$\frac{dv}{dt}$	$\frac{\text{change in velocity}}{\text{change in time}}$	$\frac{\text{feet}}{\text{second}} \Big/ \text{second}$	change in state
m	mass		$\frac{\text{weight}}{\text{acceleration of gravity}}$	$\frac{\text{pounds - second}^2}{\text{feet}}$	quantity
F = ma	force = mass times acceleration			pounds	quantity

In other words, every action has an opposite and equal reaction.

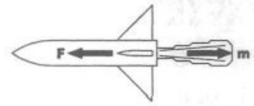
This concept was discovered by Isaac Newton who, as the story goes, was sitting under an apple tree watching the apples fall. This story is fairly close to the truth in that Newton had been attending university in London when a severe plague occurred and all of the students were sent home. Newton had time on his hands and was able t develop F = ma and the beginnings of calculus.

F = ma is Newton's way of describing the effect of gravity. In Imperial units gravity is described as:

32.17 feet / second^2

A few relationships:

$$x = vt = at^2 / 2 = v^2 / 2a$$
$$v = at = (2ax)^{1/2}$$



A B C D E F G H

JUMPING

Not considering the effects of air friction, if you jump from a 10' height, your speed when you hit the ground will be:

$$v = (2 \times 32.17 \text{ feet/second}^2 \times 10 \text{ feet})^{1/2}$$

$$= 25.37 \text{ feet/second} \qquad 17.3 \text{ miles / hour}$$

The time it takes to make this trip is:

$$t = \frac{25.37 \text{ feet/second}}{32.17 \text{ feet/second}^2} = 0.788 \text{ second}$$

Say that your footprints in the ground are 3" deep. You weigh 100 pounds. The force that you strike the ground with is:

$$v^2 = 2ax$$

$$a = v^2 / 2x$$

$$x = \frac{3 \text{ inches}}{12 \text{ inches / foot}} = 0.25 \text{ feet}$$

$$a = \frac{(25.37 \text{ feet/second})^2}{2 \times 0.25 \text{ feet}} = 1286.8 \text{ feet/second}^2$$

$$m = \frac{100 \text{ pounds}}{32.17 \text{ feet/second}^2} = 3.11 \frac{\text{pound-second}^2}{\text{feet}}$$

$$F = 3.11 \frac{\text{pound-second}^2}{\text{feet}} \times 1286.8 \frac{\text{feet}}{\text{second}^2}$$

$$= 4000 \text{ pounds}$$

This is what your feet and ankles see when you hit the ground and may cause injury.

Concrete paving has very little give. Jumping 10' onto pavement will cause injury.

ACCELERATION

A B C D E F G H

GRAVITY and THRUST

Gravity is acceleration. When you hold a ball in your hand, the force to keep that ball up is the mass of the ball times gravity.

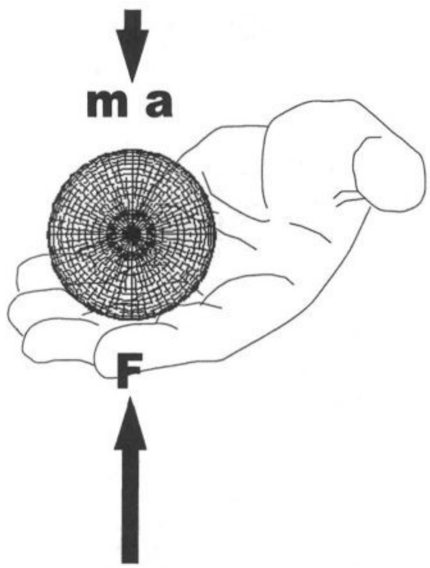


Figure 57-1 Gravity versus the force of holding an object.

Another version of **F = ma** is the rocket engine. Fuel inside the rocket is relatively at rest -- fuel inside the rocket moves at the same speed as the rocket. When the fuel is burned, it expands and is forced away from the rocket. The change in speed of the fuel molecules from **0** to **moving away** from the rocket is acceleration. The mass of the fuel times the acceleration away from the rocket equals force.

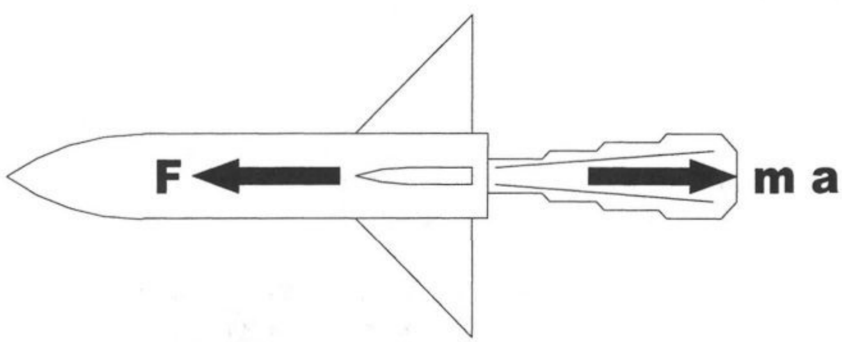


Figure 57-2 The thrust of expanding gasses accelerates the mass of the rocket.

The power of rocket and jet engines is measured in **Lbs. thrust** which is the same as saying **Lbs. force**.

A B C D E F G H

GYROSCOPIC PRECESSION

Gyroscopes serve as another example of F = ma. The "ma" is the weight of the spinning wheel and the resulting force "F" rotates the gyroscope as shown in the diagram.

Try this with a bicycle wheel. This effect helps the bike rider balance the bicycle and helps in the turn. With propeller driven aircraft, gyroscopic precession is important in the handling characteristics of the plane.

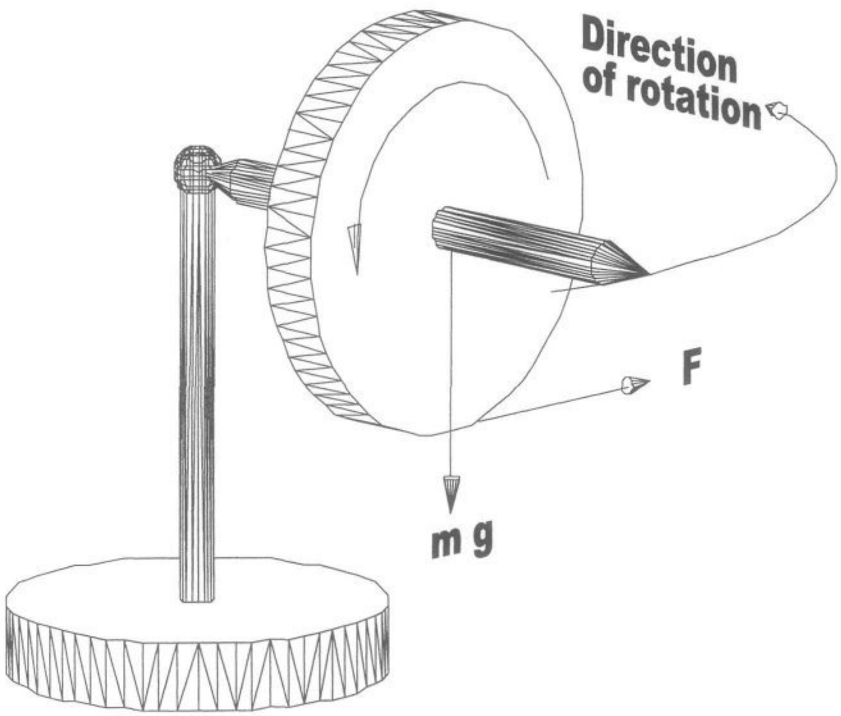


Figure 57-3 Gyroscopic precession.

The airplane propeller turns in clockwise direction as you look at it from inside the plane.
When the airplane turns to the right, the nose lifts up. When the plane turns to the left, the nose dips down.

This effect is especially important for powerful tail-dragger airplanes during takeoff. As the plane rolls down the runway, the increasing air speed allows the pilot to lift the tail so that the wings cut through the air at the right angle for take off. If the pilot uses too much power during this maneuver, the plane will veer to the left and off of the runway. This can be dangerous. It was particularly a problem for the P51 Mustang which earned it the name "Flying Coffin."

A B C D E F G H I J K L M N

Y = mX + b

y_1	= m	*	x_1	+ b	x	y
	2		5		5	2
					2	3
y_2	= m	*	x_2	+ b		
	3		2		3	2.6666667
m	-0.333		(y_1 - y_2) / (x_1 - x_2)			
b	3.667		y_1 - m * x_1			
x	3					
y	2.667		mX + b			

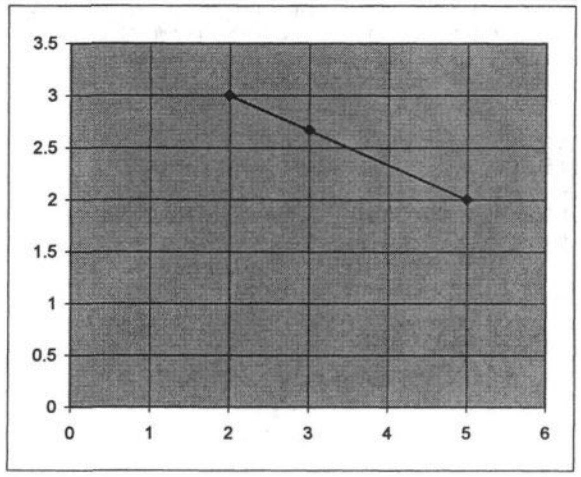


Figure 58-1 A simple straight line.

Condensed solution

c	2.667

Solution to be copied

x_1	2.5
y_1	2
x_2	5
y_2	6
x	3
y	2.800

Simplified solution to be copied

	line 1	line 2	X	Y
x_1	0	3.5	0	3.689
y_1	3.689	0	10	7.02
x_2	10	10		
y_2	7.02	6.5		
m	0.3331	1		
b	3.689	-3.5	3.5	0
formal			10	6.5
x	10.78	10.78		
	7.28	7.28	10.780	7.280
Condensed				
x	4	10.78		
y	5.02	7.28		

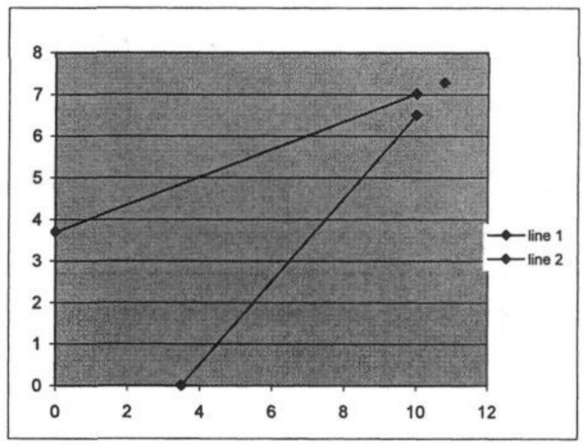


Figure 58-2 The intersection of two straight lines using y = mx + b.

Solve for the intersection of two lines

Algebra	line 1		line 2	subtract		
y	1	y	1	0		
mx	0.333	-mx	1.000	-0.667	x solution	10.780
b	3.689	-b	-3.500	7.189	y solution	7.280

row 60

Matrix

y = mx + b

y - mx = b

	y	- mx	= b	minverse		mmult intersection
line 1	1.000	-0.333	3.689	1.499	-0.499	7.280 = y
line 2	1.000	-1.000	-3.500	1.499	-1.499	10.780 = x

row 70

row 80

A B C D E F G H I J K L M N

QUADRATIC EQUATION

The quadratic equation shown below is a straight forward example of spread sheet math that makes a somewhat difficult calculation more accurate. The **ERR** flag indicates imaginary (**i**) root(s).

ax^2	bx	c
2	**-12**	**9**

$[-b + (b^2 - 4ac)^{0.5}] / 2a = 0$

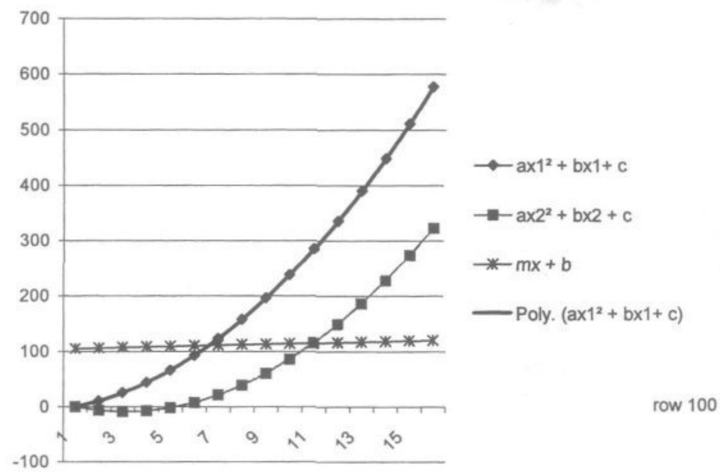
x_1	**5.12 first root**
x_2	**0.88 second root**

Assign range names of **A**, **B**, and **C** to the input values to make the equations more readable.

For a straight line y = mx + b

m	**1**	
b	**100**	this is the y intercept at x = 0

Note: as a convention, capitalized **X** and **Y** are data plots and lower case **x** and **y** are distances from the plot to a fitted line or curve. **#NUM!** is not plotted, **text** is plotted as 0.



row 100

Figure 58-3 Solutions to the quadratic equation.

Test	x_1	5.12132034	6.1213203	7.1213203	8.1213203	9.1213203	10.12132	11.12132	12.1213	13.1213	14.12	15.12
a	x_2	0.87867966	1.8786797	2.8786797	3.8786797	4.8786797	5.8786797	6.8786797	7.87868	8.87868	9.88	10.88
b	mx+b	105.12132	106.12132	107.12132	108.12132	109.12132	110.12132	111.12132	112.121	113.121	114.12	115.121
c	$ax_1^2 + bx_1 + c$	0	10.485281	24.970563	43.455844	65.941125	92.426407	122.91169	157.397	195.882	238.37	284.853
d	$ax_2^2 + bx_2 + c$	0	-6.485281	-8.970563	-7.455844	-1.941125	7.5735931	21.088312	38.603	60.1177	85.632	115.147

Linest Fit to the Quadratic Equation

x increment **0.6**

=$J$48*B44+$K$48*C44+$L$48

X	aX^2	bX	c	Y	Y linest	
0.32	0.2	-3.9	9	5.4	5.4	
0.92	1.7	-11.1	9	-0.4	-0.4	
1.52	4.6	-18.3	9	-4.6	-4.6	note that the r^2
2.12	9.0	-25.5	9	-7.5	-7.5	shows a good
2.72	14.8	-32.7	9	-8.8	-8.8	(exact) fit
3.32	22.1	-39.9	9	-8.8	-8.8	
3.92	30.8	-47.1	9	-7.3	-7.3	
4.52	40.9	-54.3	9	-4.4	-4.4	
5.12	**52.5**	**-61.5**	**9**	**0.0**	**0.0**	
5.72	65.5	-68.7	9	5.8	5.8	
6.32	79.9	-75.9	9	13.1	13.1	
6.92	95.8	-83.1	9	21.8	21.8	
7.52	113.1	-90.3	9	31.9	31.9	
8.12	131.9	-97.5	9	43.5	43.5	
8.72	152.1	-104.7	9	56.5	56.5	
9.32	173.8	-111.9	9	70.9	70.9	
9.92	196.9	-119.1	9	86.8	86.8	
10.52	221.4	-126.3	9	104.1	104.1	
11.12	247.4	-133.5	9	122.9	122.9	
11.72	274.8	-140.7	9	143.1	143.1	
12.32	303.6	-147.9	9	164.8	164.8	
12.92	333.9	-155.1	9	187.9	187.9	
13.52	365.7	-162.3	9	212.4	212.4	
14.12	398.8	-169.5	9	238.4	238.4	
14.72	433.4	-176.7	9	265.8	265.8	
15.32	469.5	-183.9	9	294.6	294.6	
15.92	507.0	-191.1	9	324.9	324.9	

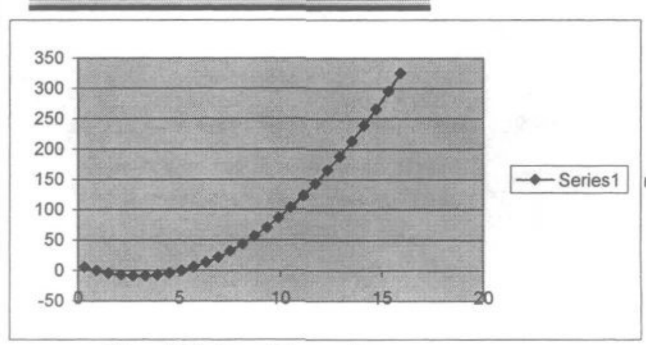
linest	m1	m2	b		
m	1.00	1.00	9.00	#N/A	
se	0.00	0	0	#N/A	
r^2	1.0000	1.7E-14	#N/A	#N/A	
F	5.024E+32	24	#N/A	#N/A	row 120
ss_{reg}	288499.03	6.9E-27	#N/A	#N/A	

=LINEST(E44:E70,B44:C70,TRUE,TRUE)

describe the **linest** range, enter the equation, and then press **[Ctrl] [Shift] [Enter]** simultaneously to get this equation throughout the range

row 130

{=LINEST(E48:E74,B48:C74,TRUE,TRUE)}



row 140

Figure 58-4 The cubic equation.

row 150

A B C D E F G H I J K L M N

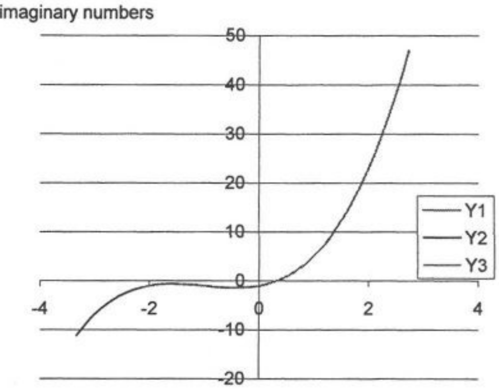
CUBIC EQUATION ALGEBRAIC and TRIGONOMETRIC SOLUTION

Typically, if the algebraic solution can provide an answer, the trigonometric solution will return **#NUM**'s and vice versa.

Algebraic Solution

i represents imaginary numbers

	p	q	r	sum = y		
	3	2	-1	0		
x^3	px^2	qx	r	= Y		
0.034	0.316	0.649	-1.000	0.000	x_1	0.325 OK
-11.010	14.847	-4.449	-1.000	-1.612	x_2	-2.225 !!! i
-1.331	3.631	-2.200	-1.000	-0.901	x_3	-1.100 !!! i



row 170

Figure 58-5 The cubic equation algebraic solution.

a -1.000 1 / 3 * (3 * q - p^2)
1 / 3 * (3 * 2.0 - 3.0^2)

b -1.000 1 / 27 * (2 * p^3 - 9 * p * q + 27 * r)
1 / 27 * (2 * 3.0^3 - 9 * 3.0 * 2.0 + 27 * -1.0)

flag 1	1 logic	$b^2/4 + a^3/27 > 0$	1 real root and 2 imaginary roots
flag 2	0 logic	$b^2/4 + a^3/27 = 0$	3 real roots of which 2 at least are equal
flag 3	0 logic	$b^2/4 + a^3/27 < 0$	3 real and unequal roots

[A] 0.987 $\sqrt[3]{-b/2 + \sqrt{b^2/4 + a^3/27}}$
(- -1.000 / 2 + SQRT (-1.000^2 /4 + -1.000^3 /27))^(1/3)

logic 1 $\sqrt[3]{-b/2 - \sqrt{b^2/4 + a^3/27}}$
(- -1.000 / 2 - SQRT(-1.000^2 /4 + -1.000^3 /27)) >= 0

B_eq 0.338 abs(-b / 2 - sqrt(b^2 /4 + a^3 / 27))^(1/3)
ABS(- -1.000 / 2 - SQRT(-1.000^2 /4 + -1.000^3 / 27))^(1/3)

row 180

[B] 0.338 If(logic, B_eq, -B_eq)
IF(1, 0.338, -0.338)

X_1 0.325 [A] + [B] -p/3
0.987 + 0.338 - 3.000 /3

X_2 -2.225 -([A] + [B]) /2 + ([A] - [B]) /2 * $\sqrt{-3}$ -p/3
-(0.987 + 0.338) /2 + (0.987 - 0.338) /2 * (-3^0.5) - 3.000 /3

X_3 -1.100 -([A] + [B]) /2 - ([A] - [B]) /2 * $\sqrt{-3}$ - p/3
-(0.987 + 0.338) /2 - (0.987 - 0.338) /2 * (-3^0.5) - 3.000 /3

Trigonometric Solution

i represents imaginary numbers

	p	q	r	sum = y		
	3	1	-2	0		
x^3	px^2	qx	r			
0.236	1.146	1.236	-1.000	1.618	x_1	0.618 !!! i
-8.000	12.000	-4.000	-1.000	-1.000	x_2	-2.000 !!! i
-4.236	7.854	-3.236	-1.000	-0.618	x_3	-1.618 !!! i

a -2.000 1 / 3 * (3 * q - p^2)
1 / 3 * (3 * 1.0 - 3.0^2)

b -1.000 1 / 27 * (2 * p^3 - 9 * p * q + 27 * r)
1 / 27 * (2 * 3.0^3 - 9 * 3.0 * 1.0 + 27 * -2.0)

cos Φ 0.919 $-b/2 / \sqrt{-a^3/27}$
- -1.000 /2 / SQRT(- (-1.000^3) /27)

arcos Φ 0.406

X_1 0.618 2 * $\sqrt{-a/3}$ * cos(Φ /3) - p /3
2 * (- -1.000 /3)^0.5 * COS(0.406 /3) - 3.000 /3

X_2 -2.000 -2 * $\sqrt{-a/3}$ * cos(Φ /3 - p /3) - p /3
- 2 * (- -1.000 /3)^0.5 * COS(0.406 /3 - PI/3) - 3.000 /3

X_3 -1.618 -2 * $\sqrt{-a/3}$ * cos(Φ /3 + p /3 * 2/3) - p /3
2 * (- -1.000 /3)^0.5 * COS(0.406 /3+2 * PI * 2/3) - 3.000 /3

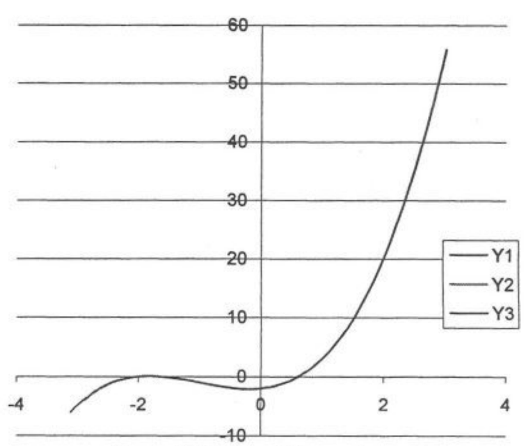


Figure 58-6 The cubic equation trigonometric solution.

row 220

A B C D E F G H I J K L M N

CUBIC EQUATION GRAPHING

For the equation **$x^3 + px^2 + qx + = 0$** , the value of **x** crosses the **Y-axis** at **y = 0**.
The graph **X-axis** is calculated around the **y = 0** value. Each **X-axis** and its corresponding **y** values are a separate series in the same graph.

Left click on the graph and right click on the **Source Data...** in the pop-up menu.
Left click on the **Series** tab to view the source data for each **xy** series.

Algebraic Solution

increment	0.1		0.1		0.1	
X axis	Y	X axis	Y	X axis	Y	
-0.775	-1.213	-3.325	-11.238	-2.200	-1.528	
-0.675	-1.290	-3.225	-9.785	-2.100	-1.231	
-0.575	-1.348	-3.125	-8.466	-2.000	-1.000	
-0.475	-1.380	-3.025	-7.275	-1.900	-0.829	
-0.375	-1.381	-2.925	-6.205	-1.800	-0.712	
-0.275	-1.344	-2.825	-5.250	-1.700	-0.643	
-0.175	-1.264	-2.725	-4.405	-1.600	-0.616	
-0.075	-1.134	-2.625	-3.664	-1.500	-0.625	
0.025	-0.949	-2.525	-3.019	-1.400	-0.664	
0.125	-0.702	-2.425	-2.467	-1.300	-0.727	
0.225	-0.388	-2.325	-2.000	-1.200	-0.808	
0.325	0.000	**-2.225**	-1.612	**-1.100**	-0.901	where y = 0
0.425	0.467	-2.125	-1.298	-1.000	-1.000	
0.525	1.020	-2.025	-1.051	-0.900	-1.099	
0.625	1.664	-1.925	-0.866	-0.800	-1.192	
0.725	2.406	-1.825	-0.736	-0.700	-1.273	
0.825	3.251	-1.725	-0.656	-0.600	-1.336	
0.925	4.205	-1.625	-0.619	-0.500	-1.375	
1.025	5.276	-1.525	-0.620	-0.400	-1.384	
1.125	6.467	-1.425	-0.652	-0.300	-1.357	
1.225	7.786	-1.325	-0.710	-0.200	-1.288	
1.325	9.239	-1.225	-0.787	-0.100	-1.171	
1.425	10.831	-1.125	-0.877	0.000	-1.000	
1.525	12.568	-1.025	-0.975	0.100	-0.769	
1.625	14.457	-0.925	-1.075	0.200	-0.472	
1.725	16.504	-0.825	-1.170	0.300	-0.103	
1.825	18.714	-0.725	-1.254	0.400	0.344	
1.925	21.093	-0.625	-1.322	0.500	0.875	
2.025	23.648	-0.525	-1.368	0.600	1.495	
2.125	26.385	-0.425	-1.385	0.700	2.212	
2.225	29.308	-0.325	-1.367	0.800	3.031	
2.325	32.426	-0.225	-1.309	0.900	3.958	
2.425	35.743	-0.125	-1.205	1.000	4.999	
2.525	39.265	-0.025	-1.047	1.100	6.160	
2.625	42.999	0.075	-0.832	1.200	7.447	
2.725	46.950	0.175	-0.552	1.300	8.866	

Trigonometric Solution row 230

0.1		0.1		0.1	
X axis	Y	X axis	Y	X axis	Y
-0.482	**-1.897**	-3.100	**-6.061**	-2.718	**-2.635**
-0.382	**-2.000**	-3.000	**-5.000**	-2.618	**-2.000**
-0.282	**-2.066**	-2.900	**-4.059**	-2.518	**-1.462**
-0.182	**-2.089**	-2.800	**-3.232**	-2.418	**-1.015**
-0.082	**-2.062**	-2.700	**-2.513**	-2.318	**-0.654**
0.018	**-1.981**	-2.600	**-1.896**	-2.218	**-0.371**
0.118	**-1.839**	-2.500	**-1.375**	-2.118	**-0.161**
0.218	**-1.629**	-2.400	**-0.944**	-2.018	**-0.019**
0.318	**-1.346**	-2.300	**-0.597**	-1.918	**0.062**
0.418	**-0.985**	-2.200	**-0.328**	-1.818	**0.089**
0.518	**-0.538**	-2.100	**-0.131**	-1.718	**0.066**
0.618	**0.000**	**-2.000**	**0.000**	**-1.618**	**0.000**
0.718	**0.635**	-1.900	**0.071**	-1.518	**-0.103**
0.818	**1.373**	-1.800	**0.088**	-1.418	**-0.237**
0.918	**2.220**	-1.700	**0.057**	-1.318	**-0.396**
1.018	**3.182**	-1.600	**-0.016**	-1.218	**-0.574**
1.118	**4.266**	-1.500	**-0.125**	-1.118	**-0.766**
1.218	**5.476**	-1.400	**-0.264**	-1.018	**-0.964**
1.318	**6.819**	-1.300	**-0.427**	-0.918	**-1.163**
1.418	**8.302**	-1.200	**-0.608**	-0.818	**-1.358**
1.518	**9.930**	-1.100	**-0.801**	-0.718	**-1.542**
1.618	**11.708**	-1.000	**-1.000**	-0.618	**-1.708**
1.718	**13.644**	-0.900	**-1.199**	-0.518	**-1.852**
1.818	**15.743**	-0.800	**-1.392**	-0.418	**-1.967**
1.918	**18.011**	-0.700	**-1.573**	-0.318	**-2.047**
2.018	**20.454**	-0.600	**-1.736**	-0.218	**-2.086**
2.118	**23.078**	-0.500	**-1.875**	-0.118	**-2.078**
2.218	**25.889**	-0.400	**-1.984**	-0.018	**-2.017**
2.318	**28.893**	-0.300	**-2.057**	0.082	**-1.897**
2.418	**32.097**	-0.200	**-2.088**	0.182	**-1.713**
2.518	**35.505**	-0.100	**-2.071**	0.282	**-1.457**
2.618	**39.125**	0.000	**-2.000**	0.382	**-1.125**
2.718	**42.961**	0.100	**-1.869**	0.482	**-0.709**
2.818	**47.021**	0.200	**-1.672**	0.582	**-0.205**
2.918	**51.310**	0.300	**-1.403**	0.682	**0.394**
3.018	**55.833**	0.400	**-1.056**	0.782	**1.095**

row 280

row 290

A B C D E F G H I J K L M N

THE SHOOTING METHOD

Algebraic Solution

i represents imaginary numbers

	p	q	r	sum = y		
	4	2	-1			
x³	px²	qx	r	= Y		
#NUM!	#NUM!	#NUM!	-1.000	#NUM!		#NUM!
#NUM!	#NUM!	#NUM!	-1.000	#NUM!		#NUM!
#NUM!	#NUM!	#NUM!	-1.000	#NUM!		#NUM!

3	2	-1	1 real root, 2 imaginary
3	12	-6	1 real root, 2 imaginary
4	2	-1	3 real and unequal roots
-3	3	-1	3 real w/ atleast 2 equal
1	-1	-1	3 real w/ atleast 2 equal

a.	-3.333	1 / 3 * (3 * 2.0 - 4.0^2)
b.	1.074	1 / 27 * (2 * 4.0^3 - 9 * 4.0 * 2.0 + 27 * -1.0)

flag 1	0	logic	b² /4 + a³ /27 > 0 1 real root and 2 imaginary roots
flag 2	0	logic	b² / 4+ a³ /27 = 0 3 real roots of which 2 at least are equal
flag 3	3	logic	b² /4 + a³ /27 < 0 3 real and unequal roots

[A].	#NUM!		(- 1.074 / 2 + SQRT (1.074^2 /4 + -3.333^3 /27))^(1/3)
logic	#NUM!		(- 1.074 / 2 - SQRT(1.074^2 /4 + -3.333^3 /27)) >= 0
B_eq	#NUM!		ABS(- 1.074 / 2 - SQRT(1.074^2 /4 + -3.333^3 / 27))^(1/3)
[B].	#NUM!		#VALUE!
		ISNUMBER	
X_1	#NUM!	0	#VALUE!
X_2	#NUM!	0	#VALUE!
X_3	#NUM!	0	#VALUE!

Trigonometric Solution

	p	q	r	sum = y	
	4	2	-1	0	daisy chained from algebraic
x³	px²	qx	r		inputs above
0.0277564	0.3666923	0.6055513	-1	-1.44E-15	OK
-36.02776	43.633308	-6.605551	-1	-8.88E-16	OK
-1	4	-2	-1	0	OK

a	-3.333		1 / 3 * (3 * 2.0 - 4.0^2)
b	1.074		1 / 27 * (2 * 4.0^3 - 9 * 4.0 * 2.0 + 27 * -1.0)
cos F	-0.459		- 0.000 /2 / SQRT(- (0.000^3) /27)
arcos F	2.047		
		ISNUMBER	
X_1	0.303	0.3027756	2 * (- 0.000 /3)^0.5 * COS(2.047 /3) - 4.000 /3
X_2	-3.303	-3.302776	- 2 * (- 0.000 /3)^0.5 * COS(2.047 /3 - PI/3) - 4.000 /3
X_3	-1.000	-1	2 * (- 0.000 /3)^0.5 * COS(2.047 /3+2 * PI * 2/3) - 4.000 /3

The value of **X** is determined by where the line crosses the **X-axis** at **Y = 0**
The trigonometric solution is used for 3 real and unequal roots.

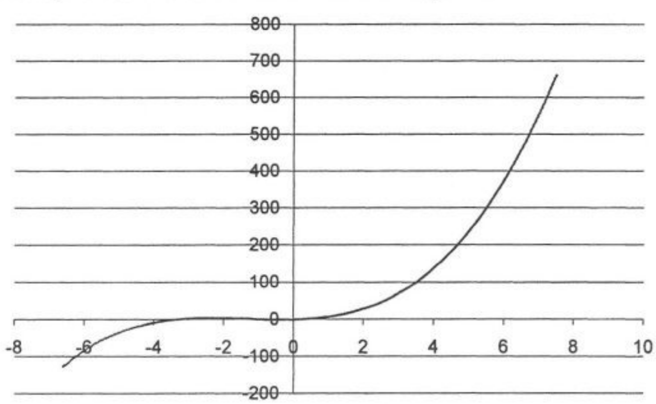
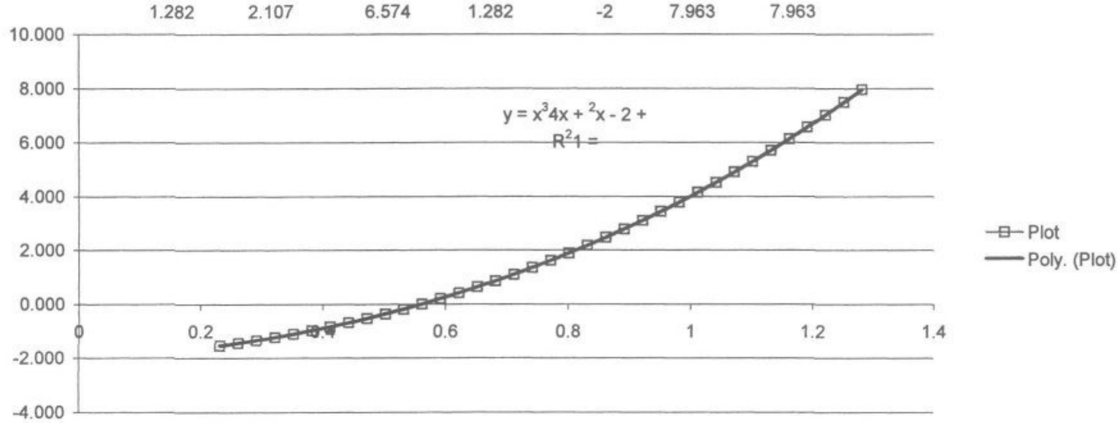


Figure 58-7 The shooting method solution.

increment

	x_1	y_1	x_2	y_2	x_3	y_3
	0.3		0.3		0.3	
	-2.997	**2.014**	-6.603	**-127.678**	-4.300	**-15.147**
	-2.697	**3.083**	-6.303	**-105.083**	-4.000	**-9.000**
	-2.397	**3.416**	-6.003	**-85.172**	-3.700	**-4.293**
	-2.097	**3.175**	-5.703	**-67.783**	-3.400	**-0.864**
	-1.797	**2.521**	-5.403	**-52.753**	-3.100	**1.449**
	-1.497	**1.616**	-5.103	**-39.920**	-2.800	**2.808**
	-1.197	**0.623**	-4.803	**-29.123**	-2.500	**3.375**
	-0.897	**-0.297**	-4.503	**-20.199**	-2.200	**3.312**
	-0.597	**-0.981**	-4.203	**-12.987**	-1.900	**2.781**
	-0.297	**-1.267**	-3.903	**-7.325**	-1.600	**1.944**
	0.003	**-0.994**	-3.603	**-3.050**	-1.300	**0.963**
where y = 0	**0.303**	**0.000**	**-3.303**	**0.000**	**-1.000**	**0.000**
	0.603	**1.878**	-3.003	**1.986**	-0.700	**-0.783**
	0.903	**4.801**	-2.703	**3.071**	-0.400	**-1.224**
	1.203	**8.932**	-2.403	**3.416**	-0.100	**-1.161**
	1.503	**14.433**	-2.103	**3.183**	0.200	**-0.432**
	1.803	**21.465**	-1.803	**2.535**	0.500	**1.125**
	2.103	**30.190**	-1.503	**1.634**	0.800	**3.672**
	2.403	**40.771**	-1.203	**0.641**	1.100	**7.371**
	2.703	**53.369**	-0.903	**-0.281**	1.400	**12.384**
	3.003	**68.147**	-0.603	**-0.971**	1.700	**18.873**
	3.303	**85.267**	-0.303	**-1.267**	2.000	**27.000**
	3.603	**104.890**	-0.003	**-1.006**	2.300	**36.927**
	3.903	**127.178**	0.297	**-0.026**	2.600	**48.816**
	4.203	**152.294**	0.597	**1.834**	2.900	**62.829**
	4.503	**180.399**	0.897	**4.737**	3.200	**79.128**
	4.803	**211.656**	1.197	**8.844**	3.500	**97.875**
	5.103	**246.227**	1.497	**14.317**	3.800	**119.232**
	5.403	**284.272**	1.797	**21.320**	4.100	**143.361**
	5.703	**325.956**	2.097	**30.012**	4.400	**170.424**
	6.003	**371.439**	2.397	**40.557**	4.700	**200.583**
	6.303	**420.883**	2.697	**53.117**	5.000	**234.000**
	6.603	**474.451**	2.997	**67.853**	5.300	**270.837**
	6.903	**532.304**	3.297	**84.928**	5.600	**311.256**
	7.203	**594.605**	3.597	**104.503**	5.900	**355.419**
	7.503	**661.516**	3.897	**126.740**	6.200	**403.488**
convergance		OK		OK		OK

A	B	C	D	E	F	G	H	N
CURVE FITTING with EXCEL TRENDLINE								
	x		p	q	r			
	0.562		**4**	**1**	**-2**			
increment	**0.03**	x^3	px^2	qx	r	y graph	y calculated	
	0.232	0.012	0.215	0.232	-2	-1.540	-1.540	
	0.262	0.018	0.275	0.262	-2	-1.445	-1.445	
	0.292	0.025	0.341	0.292	-2	-1.342	-1.342	
	0.322	0.033	0.415	0.322	-2	-1.230	-1.230	
	0.352	0.044	0.496	0.352	-2	-1.109	-1.109	
	0.382	0.056	0.584	0.382	-2	-0.979	-0.979	row 370
	0.412	0.070	0.679	0.412	-2	-0.839	-0.839	
	0.442	0.086	0.781	0.442	-2	-0.690	-0.690	
	0.472	0.105	0.891	0.472	-2	-0.532	-0.532	
	0.502	0.127	1.008	0.502	-2	-0.363	-0.363	
	0.532	0.151	1.132	0.532	-2	-0.185	-0.185	
Y intercept	**0.562**	0.178	1.263	0.562	-2	0.003	0.003	
	0.592	0.207	1.402	0.592	-2	0.201	0.201	
	0.622	0.241	1.548	0.622	-2	0.410	0.410	
	0.652	0.277	1.700	0.652	-2	0.630	0.630	
	0.682	0.317	1.860	0.682	-2	0.860	0.860	row 380
	0.712	0.361	2.028	0.712	-2	1.101	1.101	
	0.742	0.409	2.202	0.742	-2	1.353	1.353	
	0.772	0.460	2.384	0.772	-2	1.616	1.616	
	0.802	0.516	2.573	0.802	-2	1.891	1.891	
	0.832	0.576	2.769	0.832	-2	2.177	2.177	
	0.862	0.641	2.972	0.862	-2	2.475	2.475	
	0.892	0.710	3.183	0.892	-2	2.784	2.784	
	0.922	0.784	3.400	0.922	-2	3.106	3.106	
	0.952	0.863	3.625	0.952	-2	3.440	3.440	
	0.982	0.947	3.857	0.982	-2	3.786	3.786	row 390
	1.012	1.036	4.097	1.012	-2	4.145	4.145	
	1.042	1.131	4.343	1.042	-2	4.516	4.516	
	1.072	1.232	4.597	1.072	-2	4.901	4.901	
	1.102	1.338	4.858	1.102	-2	5.298	5.298	
	1.132	1.451	5.126	1.132	-2	5.708	5.708	
	1.162	1.569	5.401	1.162	-2	6.132	6.132	
	1.192	1.694	5.683	1.192	-2	6.569	6.569	
	1.222	1.825	5.973	1.222	-2	7.020	7.020	
	1.252	1.963	6.270	1.252	-2	7.485	7.485	
	1.282	2.107	6.574	1.282	-2	7.963	7.963	row 400



row 410

row 420

Figure 58-8 Using the Excel add trend function to solve the equation This solution used the 3rd power.

linest	m_1	m_2	m_3	b
m	1.00	1.00	1.00	-2.00
se	3.269E-15	1.168E-15	2.0423E-15	6.825E-16
r^2	1.0000	2.901E-16	#N/A	#N/A
F	1.151E+33	32	#N/A	#N/A
ss_{reg}	290.74466	2.694E-30	#N/A	#N/A

row 430

A B C D E F G H I J K L M N

CREATING AN ASCII FILE

ASCII files are basic text files that can be read by most spreadsheets and word processing programs.

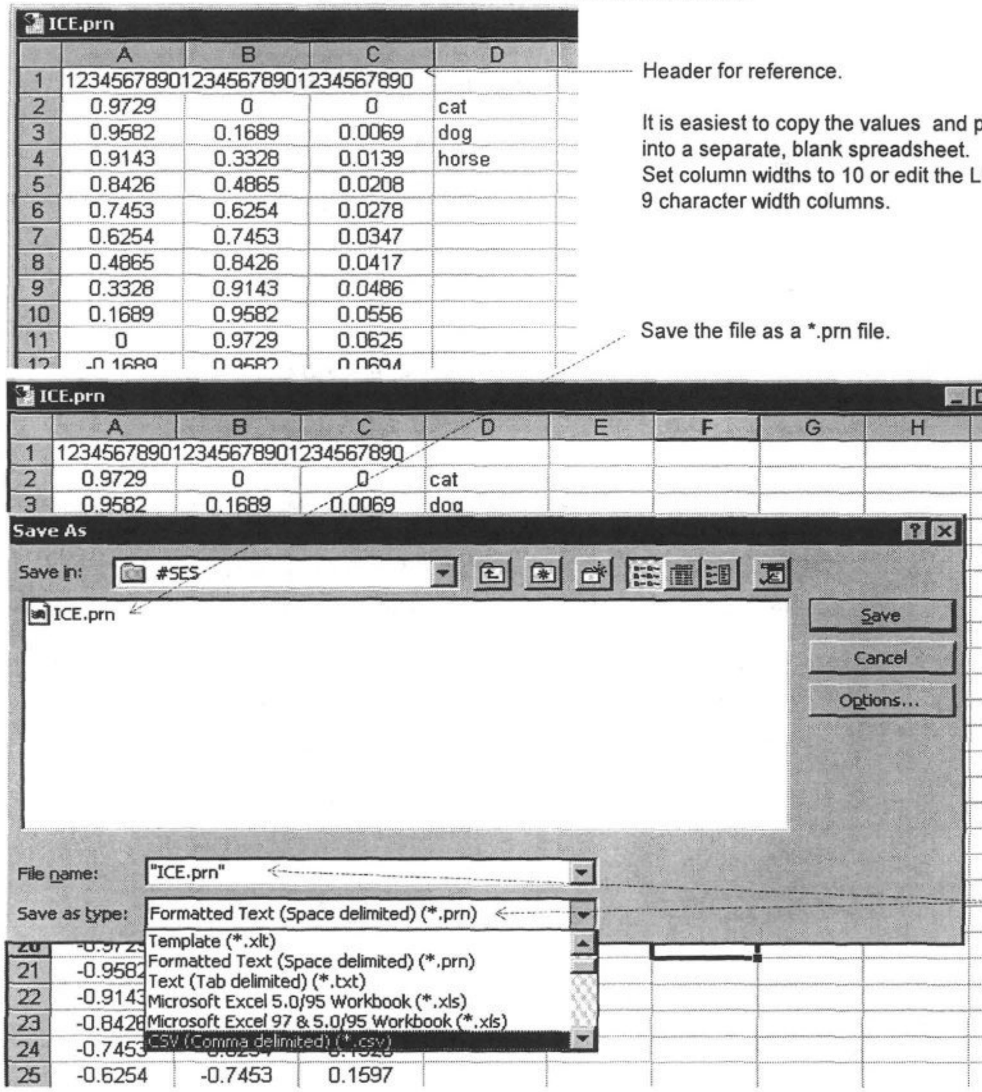
ASCII files can also be printed from the DOS prompt.

D threads **0.9729** in

	Sine	Cosine	x	y	z	
0	0.0000	1.0000	0.9729	0.0000	0.0000	cat
1	0.1736	0.9848	0.9582	0.1689	0.0069	dog
2	0.3420	0.9397	0.9143	0.3328	0.0139	horse
3	0.5000	0.8660	0.8426	0.4865	0.0208	
4	0.6428	0.7660	0.7453	0.6254	0.0278	
5	0.7660	0.6428	0.6254	0.7453	0.0347	
6	0.8660	0.5000	0.4865	0.8426	0.0417	
7	0.9397	0.3420	0.3328	0.9143	0.0486	
8	0.9848	0.1736	0.1689	0.9582	0.0556	
9	1.0000	0.0000	0.0000	0.9729	0.0625	

First, make calculations in the spreadsheet

row 20



Header for reference.

row 30

It is easiest to copy the values and paste-special-values into a separate, blank spreadsheet.
Set column widths to 10 or edit the LISP routine to read 9 character width columns.

Save the file as a *.prn file.

row 40

row 50

row 60

Be sure that (*.prn) type file is selected. This creates a space delimited file which the LISP routine can read.

The file can be reviewed with Microsoft Notepad.

Figure 59-1 Saving information as a .prn file.

row 70

READING WITH THE LISP ROUTINE

```
; 3DPLine.lsp
;
; Craig T. Christy
; INDUSTRY CONSULTING ENGINEERS
; 4334 S.W. Washouga Avenue
; Portland, Oregon 97202
; 503 246 9222
;
; Data can be generated in Excel, then copy clipped and pasted for values
; into a plane spreadsheet. Save as "name".prn.
; Plot the line in its own, blank window. Make sure that the window is
; large enough to plot the line. Trim the plotted line as required.
; Record your data as follows:
;
; 123456789012345678901234567890
;   0.8466      0          0
;   0.8338      0.147      0.0069
;   0.7956      0.2896     0.0139
;
(defun C:3DPLine (/ FILE EOF OldPD COUNT RFILE vertex
                  X Y Z DATA  BLANK_LINE )          ; define function variables
;
;; Get the Scale Factor
  (setq SF                                          ; scale factor
   (getreal "\nScale factor.....................< 1.0 > ? : ") )
 (if (or (= SF "")(= SF nil))(setq SF 1.0)  )       ; set scale to 1 if nil end if
;; Get the data file with extension
 (setq   RFILE                                      ; variable name, use FindFile for current directory
 (FindFile (getstring "\n.....................INPUT File with EXTension: ")))


 (setq FILE (open RFILE "r")                        ; open file to read
     EOF "NO"                                       ; set end of file to no
     OldPD (getvar "PDMode")                        ; save Pdmode point display style
     COUNT 0                                        ; set counter to 0
     BLANK_LINE 1 )                                 ; set blank line & end setq
;
  (setvar "BlipMode" 1)
  (setvar "CMDEcho" 0)
  (setvar "PDMode" 0)                               ; set pdmode
;
  (command "3DPOLY" 0.001 1  "")                    ; create 3D polyline to be edited
  (read-line FILE)                                  ; dummy line read
  (setq DATA (read-line FILE))                      ; read in first line of data
      (setq X     (atof (substr DATA  1 10))        ; get x value
            Y    (atof (substr DATA 10 20))         ; get y value
            Z    (atof (substr DATA 10 30))         ; get z value
            vertex  (list X Y Z) )                  ; x y z value & end setq
 (command "pedit" 0.001 "edit" "insert" vertex "")  ; edit 3D polyline vertex
```

The 3DSpiral routine reads each row of the ASCII.prn file and edit the vertex of a dummy 3DPolyline.

Be sure that the window is big enough to plot the entire object or plotting errors will occur.

This plot has been trimmed with the Acad Trim command

This command creates the dummy 3DPolyline

These values describe the start and end of each column.

This command edits the 3DPolyline described as 0.001

A	B	C	D	E	F	G	H	I	J	K	L	M	N

READING WITH THE LISP ROUTINE -- Continued

```
;; Enter while loop to start processing point
  (while (= EOF "NO")                              ; while
    (setq COUNT (+ COUNT 1))                        ; setq Increment counter
    (if (= DATA nil)                               ; if data is nil
     (setq EOF "YES")                              ; declare end of file
      (progn                                       ; else
       (setq X    (atof (substr DATA  1 10))        ; get x value
             Y    (atof (substr DATA 10 20))        ; get y value
             Z    (atof (substr DATA 20 30))        ; get z value
             vertex  (list X Y Z) )                ; x y z value & end setq
       (command  "insert" vertex "")                ; edit 3D polyline
       (setq DATA (read-line FILE))                  ; read next line of data & end setq
       (if (= DATA "¨")                            ; if data is <Alt-168>
       (setq COUNT 0                               ; start next line set count to 0
             DATA (read-line FILE) )                ; read next line of data & end setq
       )                                          ; end IF
     )                                            ; end progn
    )                                             ; end IF
  )                                               ; end while
(command "exit" "exit" )                           ; exit 3D polyline editing
(close FILE)
(command "PDMode" OldPD )                           ;restore the original PDMode
; Exiting message
  (princ "\nFinished plotting 3D polyline.......")
  (princ)
)                                 ; end defun
```

Edit the X, Y, and Z values to change the column widths

row 140

row 150

row 160

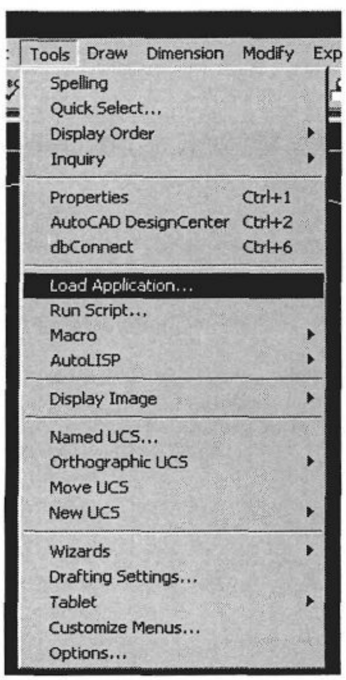


Figure 59-3 Load the LISP routine in AutoCAD with the Tools Load Application menu.

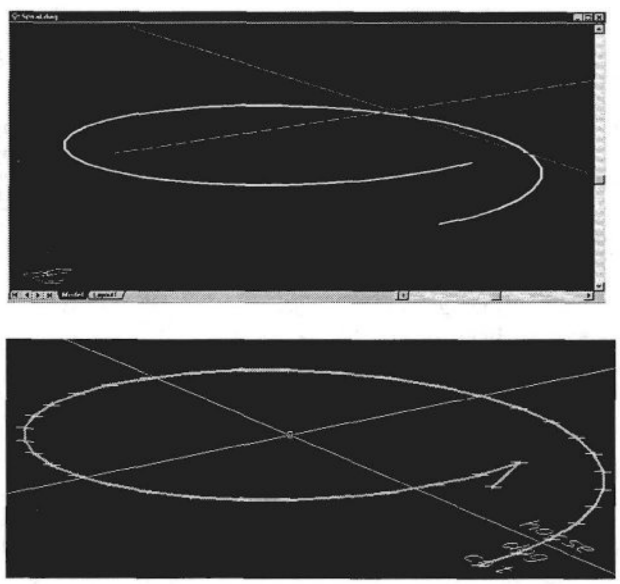


Figure 59-2 The 3D spiral generated from calculations in the spreadsheet and plotted by the LISP routine.

row 170

row 180

row 190

UNITS CONVERSION

A	B	C	D	E	F	G	H	I	J	K	L	M	N
UNITS CONVERSION													
gravity	9.80621	m/sec^2		meters / second = m/sec^2 second		at 45 degrees latitude							
gravity	32.1725	ft/sec^2											
Distance	**1**	inch	25.4	mm exact conversion									
	1	feet	304.80	mm	12 in * 25.4 mm/inch								
	1	yard	91.44	mm	3 ft * 12 in/ft * 25.4 mm/inch								row 20
	1	mm	0.03937	in	1000	μ	1000000	n	10,000,000	ångstrom			
	1.0E+00	mm			1.0E+03	μ	1.0E+06	n	1.0E+07	ångstrom			
	1	meter	3.28084	ft	0.91440	yard							
	1	kilometer	0.62137	mile									
	1	mm											
	1	μ	0.001	mm	1000	n	10000	ångstrom					
			1.0E-03	mm	1.0E+03	n	1.0E+04	ångstrom					row 30
Area	**1**	m^2	1.19599	yard^2	10.7639	ft^2	1550.0	in^2					
	1	Km^2	2.59000	Mile^2									
	1	ft^2	0.09290	m^2									
	1	yard^2	0.83613	m^2									
	1	in^2	645.160	mm^2									
													row 40
Weight	**1**	lb av	0.4536	kilogram	14.5833	oz troy							
	1	oz av	28.3495	gram	1.09714	oz troy			437.5	grains			
	1	lb av	453.592	gram	16	oz av	1.21527	lb troy	4739.7	grains			
	1	oz troy	31.1035	gram	0.91146	oz av	0.08333	lb troy	24	grains		7.78 carats	
	1	lb troy	373.242	gram	12	oz troy	0.82286	lb av	5760	grains			
	1	ton	907.185	kg	2000	lbs							
													row 50
	1	gram	0.001	kg	0.03527	oz av	15.43236	grains					
	1	kg	1000	g	2.20462	lb							
	1	metric ton	1000	kg	2205	lbs							
mass	**1**	kg	9.80621	kg-m/sec^2	70.9284	lb-sec^2 /ft							
	1	lb	4.44801	kg-m/sec^2	0.03108	lb-sec^2 /ft							
													row 60
													row 70

UNITS CONVERSION -- Continued

A	B	C	D	E	F	G	H	I	J	K	L–M	N
				SI		SI		SI		mks		
Pressure	1	lb /ft^2	0.047880	kPa	0.04788	kN / m^2	0.47000	kg /m-sec^2	4.88243	kg /m^2		
	1	lb /in^2	6.894757	kPa	0.00689	kN / mm^2	0.06768	kg /m-sec^2	0.03391	kg /m^2		
	1	Pa	1	N /m^2	0.00981	kg /m-sec^2						
	1	Pa	0.000001	N /mm^2	0.00001	kg /mm-sec^2		Imperial		Imperial		
	1	kPa	1	kN / m^2	9.80621	kg /m-sec^2	0.1450	lb /in^2	20.8854	lb /ft^2		
	1	GPa	1000	kN / m^2	9806.21	kg /m-sec^2	145.04	lb /in^2	20885.4	lb /ft^2		
	1	N /mm^2	0.000001	kN / mm^2	0.00981	kg /m-sec^2	0.0001	lb /in^2	0.00002	lb /ft^2		row 80
	1	kg /m^2	0.009806	kPa	0.09616	kg /m-sec^2	0.0014	lb /in^2	0.20482	lb /ft^2		
	1	kg /mm^2	9806.210	kPa	96161.8	kg /m-sec^2	1422.3	lb /in^2	204816	lb /ft^2		
	1	bar	101.325	kPa	14.7	psi	1.00	atmosphere	760	mm Hg		
			1013250	dynes/cm^2								
Moment	1	ft-lb	1.355757	Nm	0.13825	kg-m						
	1	Nm	0.737595	ft-lb	0.10198	kg-m						row 90
Volume	1	m^3	35.31466	ft^3	1.30795	yard^3						
	1	litre	0.264172	gallon								
	1	ft^3	0.028317	m^3	1728	in^3						
	1	yard^3	0.764555	m^3	27	ft^3						
	1	gallon	3.785412	litre	0.1337	ft^3	128	fluid oz				
					4	quarts	8	pints				
												row 100
Velocity	1	m/sec	3600	m/hr	3.28084	ft/sec	2.23694	miles/hr				
	1	km/hr	0.2778	m/sec	0.9113	ft/sec	0.62137	miles/hr				
	1	km/sec	3600	km/hr	42520	ft/sec	28991	miles/hr				
	1	ft/sec	0.3048	m/sec								
	1	miles/hr	0.44704	km/hr								
	1	mm/μsec	0.1	cm/μsec	1000000	mm/sec	1000	m/sec	3280.84	ft/sec		
			3600000	m/hr	3600	km/hr			2454.545	miles/hr		
												row 110
Force	1	lb force	4.44822	N	444822.2	dynes	43.62216	kg-m/sec^2	0.03108	lb-sec^2 /ft	slug	
	1	N	9.80665	kg-m/sec^2	100000	dynes	0.2248	lb force	0.00699	lb-sec^2 /ft	slug	
Temperature												
	0	°C	273.15	°K	32.0	°F	32 + 9 /5 * C degrees					
	39.2	°F	498.87	°R	4.0	°C	(F degrees - 32) * 5 /9					
												row 120
Energy	1	joule	10000000	ergs	0.239	cal	0.000948	Btu	2.78E-07	kW-h		
			1.0E+07	ergs								
												row 130

UNITS CONVERSION

A B C D E F G H I J K L M N

NOTATION

Imperial	feet-pounds-seconds	mks	meters-kilograms-seconds a rational metric system	SI	System Internationale
ft	foot	m	meter	KPa	Kilopascal
in	inch	mm	millimeter	MPa	MegaPascal
		cm	centimeter = 10 millimeters	N	Newton
ft^2	square foot, f^2	mm	millimeter	Nm	Newton Meter
ft^3	cubic foot, ft^3	A	ångstrom		
in^2	square inch, in^2				
in^3	cubic inch, in^3				
		m^2	square meter, m^2		
oz av	avoirdupois ounce	m^3	cubic meter, m^3		
oz troy	apothecary ounce	gr	gram		
		kg	kilogram		
		tonne	metric ton		
		kfg	kilograms force (Japanese)		
psf	pounds per square foot, lb $/ft^2$				
psi	pounds per square inch, lb $/in^2$				
F	Fahrenheit degrees	C	Centigrade degrees		
R	Rankine degrees	K	Kelvin degrees		
cal	calorie				
Btu	British thermal unit				
kW-h	kilowatt hour				

Prefix Summary

p	10^{-12}	pico	0.000 000 000 001
n	10^{-9}	nano	0.000 000 001
µ	10^{-6}	micro	0.000 001
m	10^{-3}	milli	0.001
k	10^{3}	kilo	1 000
M	10^{6}	mega	1 000 000
G	10^{9}	giga	1 000 000 000
T	10^{12}	tera	1 000 000 000 000

Density
1 Litre of water = 1 cubic decimeter = 1 kilogram

density	**1**	kg/m^3	0.06246	lb/ft^3	
water	**999.36**	kg/m^3	62.42	lb /ft^3	at 39.2°F, 3.98°C
steel	**7850**	kg/m^3	490.35	lb/ft^3	
concrete	**2400**	kg/m^3	149.92	lb/ft^3	

Speed of Sound

dry air 0°C	331	m/sec	1192896	m/hr	1087	ft/sec	741	miles/hr	
mild steel	5960	m/sec	21456000	m/hr	19554	ft/sec	13332	miles/hr	
pyrex glass	5640	m/sec	20304000	m/hr	18504	ft/sec	12616	miles/hr	
kerosene	1324	m/sec	4766400	m/hr	4344	ft/sec	2962	miles/hr	at 25°C
water	1498	m/sec	5392800	m/hr	4915	ft/sec	3351	miles/hr	at 25°C, distilled

A B C D E F G H I J K L M N

Distance, Velocity and, Acceleration

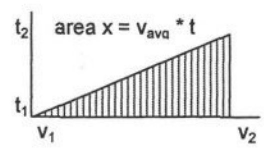
Linear Distance

x_1	**0**	inch
x_2	**4**	inch
Dx	4	inch
$x_{average}$	2	inch
v_1	**0**	inch /sec
v_2	**4**	inch /sec
Dv	4	inch /sec
$v_{average}$	2	inch /sec
t_1	**2**	sec
t_2	**4**	sec
Dt	2	sec
$t_{average}$	3	sec
a	**2**	in /sec^2

row 200

row 210

x 4 inch $(v_2 + v_1)/2\ (t_2 - t_1)$
v_{avg} /Dt
2.00 in/sec * 2.00 sec



x 4 inch $(v_2 - v_1)^2 / 2a$
Dv^2 / 2a
$4.00^2\ in^2/sec^2\ /(2\ 2.00\ in/sec^2)$

row 220

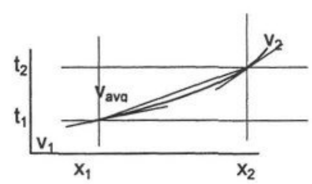
x 4 inch $(v_2^2 - v_1^2)/2a$
$(4.00\ in^2/sec^2 - 0.00\ in^2/sec^2)\ /(2 * 2.00\ in/sec^2)$

x 4 inch $(t_2 - t_1)^2\ a/2$
$(2.00\ sec - 4.00\ sec)^2 * 2.00\ inch/sec^2\ /2$

Velocity

v 2 inch /sec $(x_2 - x_1)/(t_2 - t_1)$
(4.00 - 0.00) in /(4.00 - 2.00) se

row 230



v 4 inch /sec $a\ (t_2 - t_1)$
$2.00\ in/sec^2 * (4.00 - 2.00)\ sec$

v 2.83 inch /sec $\sqrt{2\ a\ (x_2 - x_1)}$
$\sqrt{2 * a\ in/sec^2 * (4.00 - 2.00\ in)}$

row 240

Acceleration

a 2 inch /sec^2 $(v_2 - v_1)/(t_2 - t_1)$
(4.00 - 0.00) in /sec /(4.00 - 2.00) sec

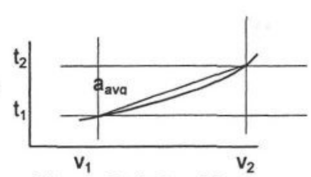


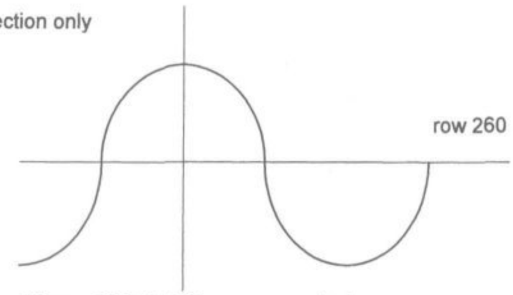
Figure 60-1 Graphic representations of changes in time vs velocity vs distance.

row 250

A B C D E F G H I J K L M N

Convert Hp to Work

F	**9.60**	k	cyclical load applied
delta	**0.50**	in	1/2 of stroke — 0.020 * 96" max drift
T	**1.50**	sec/cycle	time for complete cycle + and - deflections
energy	2.40	in-k	P * delta /2 for 1/2 of stroke force applied one direction only
power	0.900	in-k / sec	
Hp	0.550	ft-k/sec	constant
Hp	0.046	in-k/sec	constant
Hp_req	19.6	hp	in straight line
rpm_req	40	rpm	
motor	3.0	Hp motor	



row 260

Figure 60-2 Rotation represented as a sine wave.

As Impact -- Spring compressed by piston

P_stroke	**9.60**		
arm	**0.50**		
V_init	**1.00**	in/sec	
V_final	0		
time	0.375	sec	
k_spring	19.2	k/in	
Theta	90	deg	
cos_t	0.000		COS(Theta /180 * PI())
sin_t	1.000		SIN(Theta /180 * PI())
v	1.000	in/sec x	V_init * sin_t
F	0.00		P_stroke * cos_t
Torque	0.00	k-in	F * arm * sin_t
Theta	135	deg	
cos_t	-0.707		
sin_t	0.707		
v	0.707	in/sec x	
F	-6.79		
Torque	-2.40	k-in	
Theta	180	deg	
cos_t	-1.000		
sin_t	0.000		
v	0.000	in/sec x	
F	-9.60		
Torque	0.00	k-in	
TEST	140	deg	
cos_t	-0.766		
sin_t	0.643		
v	0.643	in/sec x	
F	-7.35		
Torque	-2.36	k-in	

row 270

row 280

row 290

Figure 60-3 Convert torque to linear force.

row 300

As Function of Motor Torque

throw	**0.25**	in
F	9.6	k
Torq	2.40	k-in
rpm	**40.00**	rpm
	0.67	hz
Hp	1.5	hp
V_top	0.523441	in/sec

row 310

ENGINEERING with the SPREADSHEET

61 Notation.xls

A	B	C
GENERAL		
#NUM	a problem occurs with a number in a formula or a function	
$	cell row and/or column absolute reference	
&	ampersand used in string concatenation	
.mpr	ASCII file extension used in AutoCAD	
[Ctrl] [Shift] [Enter]	table entry command	
[F2]	edit key	
[F4]	absolute reference key	
[F5]	moving around the spreadsheet	
		row 20
absolute reference	how a cell is referenced by a formula, $	
Ad^2	area * (distance from an axis)^2. moment of inertia . in^4	
ampersand	& used in concatenating/combining text and equations	
AND	Boolean logical operator	
ASD	allowable stress design	
atan	arctangent, radians	
b	the Y intercept in a graph	
$bd^3/12$	moment of inertia for a rectangle, in^4	
		row 30
c	speed of pressure wave, celerity, ft/sec	
c	actual damping, lb-sec/in	
c	distance of centroid to the extreme fiber in tension or compression, inches	
c_c	*critical damping, lb-sec/in*	
celerity	movement of the pressure wave in a pipe	
CG	center of gravity	
CG X →	CG located in the X direction from the Y axis.	
d, d_X	distance, distance from the x-axis	
E	Young's modulus of elasticity, 29,000 ksi for steel, first yield, ksi, k/in²	row 40
e	2.71828 base of natural logarithms	
Ek	kinetic energy	
Ep	potential energy	
f	1 /T, Hz, cycles per second	
F	force as in F = ma, F = m z", lbs	
FEM	fixed end moment as opposed to pinned end with no moment resistance	
FEM	fixed end moment	
f_n	natural frequency, cycles per second, Hertz $\omega_n/2\pi$, 1/T	
		row 50
g	gravity, 32.17 ft/sec/sec, 386.04 in/sec², 9.80621 m/sec²	
Greek C	font	
Greek S	font	
Hz	Hertz, cycles/sec	
i	complex conjugate, *imaginary number*	
I	moment of inertia, in^4	
iterative solution	the shooting method -- converging two equations to within a degree of accuracy	
I_{XX}, I_{YY}	moments of inertia about x-axis and y-axis respectively, in^4	

A	B	C
GENERAL -- Continued		
k	number of constants in an equation	
k	stiffness factor, k/in	
K	liquid bulk modulus of elasticity for water this is usually 300 ksi unless the water contains a significant air bubbles as in papermill stock lines. Air bubbles are compressible and the value of K must be reduced.	
K.E.	kinetic energy	
L	length of beam or column, in	
LRFD	load resistance factor design	
LVDT	linear voltage displacement transducer	
		row 70
m	the slope of straight line in a graph	
m	mass, $lb\text{-}ft/sec^2$, $kg\text{-}m/sec^2$	
M	moment	
m, mass	weight / gravity, $k\text{-}sec^2/in$, $kg\text{-}sec^2/m$	
moment distribution	a method of solving multi-span beam-column moments and reactions created by Mr. Hardy Cross, hence, also referred to as the Hardy Cross method	
n	number of bolt threads	
n	Poisson's ratio 0.27 to 0.3 for steel	
NOT	Boolean logical operator	
		row 80
OR	Boolean logical operator	
P.E.	potential energy	
p-delta, pd, $P\Delta$	an effect that takes place in columns and slender walls where a column is already bent and an axial load is applied to it, it will bend more.	
pline	AutoCAD contiguous line	
q	soil pressure, k/ft^2	
Q	flowrate in pipe, ft^3/sec	
R_e	Reynolds number, unitless factor for air flow	
right hand rule	mathematical rule -- an arrow going away from you rotates in a clockwise direction	
r_o	soil modulus of compressibility, $lbs/in^2/in$, lbs/in^3	row 90
S	section modulus, I/c, in^3	
s, σ	stress, psi, lb/in^2, ksi, k/in^2, kg/cm^2, kPa	
Script S	font	
seismic	earthquake, E, fraction of gravity, force	
shooting method	converging two equations to within a degree of accuracy	
Symap	font	
Symath	font	
Symbol	font	
SymbolSH	font	row 100
Symeteo	font	

A	B	C
GENERAL -- Continued		
T	period, seconds	
t	time at which z' is calculated, second	
tabs		
TLA	three letter acronym	
V	shear	
v	velocity, in/sec	row 110
w	uniform load, k/ft	
w	uniform load, lbs/inch	
X_{mm}	overall mean denoted in text books as X with double bars on top	
z'	velocity, in/sec	
z"	acceleration, in/sec²	
z_c	known as x_0 in some references, resulting displacement, inch	
ZIP	ZIP files (WinZip®) are condensed files for storage and transmission	
δ	deflection, inches	
ζ, ξ	damping factor, unitless	row 120
π	PI() in Excel nomenclature, 3.142, unitless	
ρ	density of the liquid, lb/ft³, where water = 62.4 lb/ft³	
σ	stress, k/in²	
τ	duration of applied force, second	
BOLTS		
F/thread	Fv * area of thread in shear	
F_t	tension, kips/in²	
F_v	shear through threads in plane, kips/in²	
H	0.866 P	row 130
head	bolt head	
K root	least diameter of a bolt at the threads	
n	number of threads/inch	
pitch	spacing of threads, inch	
w thread	actual width of thread pitch - pitch/4	
CELERITY -- WAVE ACTION		
b, circ	shell circumference, ft	
C_1	arbitrary factor, unitless	
C_2	lateral seismic force coefficient, unitless	row 140
D	tank diameter, ft	
density	density of stored product, k/ft³	
d_{wave}	wave height, ft	
F_a	minimum yield strength in compression, k/in²	
F_{by}	minimum yield strength in bending, k/in²	
G	specific gravity of stored product, unitless	
H	maximum design liquid height, ft	
H_t	total height of tank shell, ft	
I	wind or seismic importance factor, unitless	row 150
k	factor for D/H	

A	B	C
CELERITY -- WAVE ACTION -- Continued		
M_{ot}	tank overturning moment, k-ft	
M_{rt}	righting moment, k-ft	
S	site amplification factor from API Table L-2	
T	period of first mode sloshing, sec	
tank_full	weight of full tank, k	
t_b	thickness of bottom of tank, in	
t_s	shell thickness, in	
V	volume of tank, ft^3	row 160
W arm	vertical arm to lateral forces, ft	
W sum	for lateral forces, k	
W_{tank}	tank shell per foot of circumference, k/ft	
W_r	total weight of tank roof and insulation, 0 when included in Ws, k	
$W_{s\ tare}$	weight of empty tank, tare, k	
W_T	weight of liquid, k	
X_s	height to the CG of the shell usually taken as 2/3 Ht for flexible structures, ft	
Z	seismic zone coefficient, unitless	
σ	longitudinal stress at bottom of the shell, lbs/in^2	
		row 170
CONCRETE PULLOUT		
μ	concrete roughness factor	
A_b	net cross-section area of bolt	
A_c	shear area A_C (base plate or shear plane)	
A_P	effective area of projected cone onto the surface of the slab	
d_e	edge distance **toward** loaded edge	
Edge 2	edge distance **away** from loaded edge	
f'_c	compression strength of concrete	
f_{ut}	bolt ultimate tensile strength	row 180
f_y	specified yield strength = F_u tensile for bolt material	
λ	concrete weight factor	
Φ	concrete strength reduction factor	
CONCRETE FOUNDATION DESIGN		
a_X	the 1/3 point of the triangular soil loading profile, ft	
CG_X	center of gravity from the x-axis, ft	
d_{20}	deflection indexed to soil modulus, inch	
e_X	eccentricity of all loads including dead and live loads, the slab, and moment due to seismic or wind forces located from the geographical center of gravity CG_X, ft	row 190
I_{XX}	moment if inertia about the x-axis or an axis parallel to the x-axis, ft^4	
Mot_X	overturning moment about the x-axis, k-ft	
Mrt_X	righting moment about the x-axis from loads	
M_u	ultimate moment for LRFD design	
M_X	moment about the x-axis or an axis parallel to the x-axis, k-ft	
q_x	soil pressure along the loaded top or bottom edge, ksf, working in the opposite direction of Mot x, k-ft	

A	B	C
SEISMIC		
a_p	*in-structure component amplification factor*	
C_a	CA seismic coefficient soil type	row 200
C_t	structural frame type factor	
C_v	seismic coefficient soil profile	
F_p	attached structure force * W	
h_r	*to top of structure above grade, ft*	
h_x	element connection elevation above grade, ft	
I_p	attached structure importance factor	
m	graph slope of straight line	
n	number of samples	
n_1	factor for the groups in the F statistic	
n_2	factor for the number of observations within a number of groups	row 210
N_a	seismic near-source factor	
N_v	seismic near-source factor	
R	structure response factor	
S_A	Hard rock soil profile	
S_B	Rock soil profile	
S_C	Very dense soil & soft rock soil profile	
S_D	Stiff soil profile	
S_E	Soft soil profile	
S_F	Soil requiring evaluation soil profile	row 220
soil	soil profile type measured as blows/ft	
T	structural period, seconds/cycle	
Z	*seismic zone factor*	
Ω	seismic force amplification factor required for structural overstrength	

A	B	C
STATISTICS		
b	the Y-axis intercept the point at which the line starts for a given value of X and Y along the slope m	
CM	correction for the mean	
df	degrees of freedom n - k	row 230
F statistic	MST / MSE the chance relation between data groups and within a group the F statistic determines whether the observed relationship between dependent and independent variables occurs by chance. Always positive	
k	number of constants in the equation	
m	the slope of a straight line in y = mx + b	
MSE	mean square for error	
MST	mean squares for treatment	
n_1	factor for the groups in the F statistic	
n_2	factor for the number of observations within a number of groups	
R Square, r^2	the correlation of estimated and actual y values. A measure correlation varies from 0 to 1 with 1 being the best correlation	
s, s coefficient	standard deviation, standard measure of dispersion	
SS Residual, SSE	sum of squares for error = $S(Y - Y_m)^2$	row 240
ssreg	the sum of the squared differences for the actual values and the average y values for each point	
standard error se	the standard error values for the coefficients m1, m2, etc.	
Syx	Standard Error of Estimate of the dependent variable Y regressed against the independent variable(s) X	
t	Student's t -- describes the sampling distribution of a deviation from the population mean divided by the standard error	
two tail	excluded areas of a Gaussian curve in statistics	
V	lateral force, * W	
X_m Y_m	the mean value(s) of X and Y	
X_{mm}	overall mean denoted in text books as X with double bars on top	
Y = mX + b	straight line graph	
y intercept	where a straight or curved line crosses the y-axis, sometimes set to 0	row 250
Y_c	the computed/expected value of y	
β	a pure number representing the net regression coefficient expressed in units of its own standard deviation.	
β	a pure number representing the net regression coefficient expressed in units of its own standard deviation.	
Σx^2	Σx^2 represents standard error of regression coefficient: the dispersion of X values around their mean.	

ENGINEERING with the SPREADSHEET

61 Notation.xls

A	B	C
VORTEX		
C_D	coefficient of drag	
C_L	coefficient of lift	
D	max stack diameter at CL of plate	
d	diameter of cylinder perpendicular to wind flow, ft	row 260
d	logarithmic decrement for damping	
$D_{cantilever}$	amplified deflection	
d_mean	diameter of cylinder to middle of plate, ft	
D_r	average diameter of stack for DPE calculations	
D_s	static deflection for DPE calculations	
E	Young's modulus of elasticity, ksi	
E heat	modulus of elasticity at operating temperature, ksi	
$E_{\_ASD}$	g_working = Code Seismic /1.4	
f_n	natural frequency, 1 /Tn frequency, cycles/second	
f_v	shedding frequency of vortices, Hz	
Fy	first yield strength, ksi	
g	gravity, 386 in/sec², 32.2 ft/sec²	row 272
H_r	spacing between stiffener rings	
k	spring constant, lb/in	
K_1'	*ratio of force to structure weight*	
K_1''	ratio of force to structure weight and modulus	
L	height of stack/structure from TANK inputs	
L_	force on stack at critical wind velocity	
M vortex	vortex induced moment	
M.F.	magnification factor, conservatively p /d	
M.F.	foundation magnification factor	
m_air	viscosity of air, lb-sec/ft²	row 282
mass	W /g, lb-sec²/in	
$q_{critical}$	pressure at critical wind velocity, psf, lb/ft²	
q_{wind}	0.00257 * (V mph)² generic wind pressure calculation	
R_e	Reynolds number, unitless	
s	stress, ksi, k/in²	
S	*dimensionless parameter, Strouhal number*	
S_m	required section modulus at ring	
t	temperature, degrees Fahrenheit	
t, t'	corroded plate thickness	
T_n	natural, resonant frequency of structure	row 292
V	wind velocity, ft/sec	
V_1	first critical velocity at which vortex shedding frequency equals the natural frequency of the structure	
V_wind	possible vortex shedding wind speed where R_e<50,000	
V_wind	vortex shedding per resonant frequency of structure	
W	weight, lbs	
β	type of construction factor	
ε	coefficient of expansion, unitless	
$\varepsilon_{damping}$	damping factor for type of structure	
Θ	angle used in calculating a partially loaded ring, radians	
ρ_air	air mass density, lb-sec²/ft⁴	row 302

A	B	C
WIND		
C_e	Gust Factor Coefficient	
C_q	pressure coefficient	
Exposure	Exposure and gust factor coefficient B, C, or D	
I	importance factor	
P wind	pressure of wind, lbs/ft²	
q_s	wind pressure at a designated height, lbs/ft²	
Q_s	wind stagnation pressure at standard height	
V wind	velocity of wind, miles/hour	row 312
V_basic	basic wind speed, miles/hour	

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NOTES

ENGINEERING with the SPREADSHEET

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