STRUCTURAL AND EARTHQUAKE ENGINEERING SOFTWARE

ETABS

version 8

Integrated Building Design Software

CONCRETE SHEAR WALL DESIGN MANUAL

A Product of Computers & Structures, Inc.

COMPUTERS & STRUCTURES INC.

ETABS®

Integrated Building Design Software

Concrete Shear Wall Design Manual

COMPUTERS & STRUCTURES INC.

Computers and Structures, Inc.
Berkeley, California, USA

Version 8
January 2002

Copyright

Further information and copies of this documentation may be obtained from:

Computers and Structures, Inc.
1995 University Avenue
Berkeley, California 94704 USA

Phone: (510) 845-2177
FAX: (510) 845-4096
e-mail: info@csiberkeley.com (for general questions)
e-mail: support@csiberkeley.com (for technical support questions)
web: www.csiberkeley.com

DISCLAIMER

CONSIDERABLE TIME, EFFORT AND EXPENSE HAVE GONE INTO THE DEVELOPMENT AND DOCUMENTATION OF ETABS. THE PROGRAM HAS BEEN THOROUGHLY TESTED AND USED. IN USING THE PROGRAM, HOWEVER, THE USER ACCEPTS AND UNDERSTANDS THAT NO WARRANTY IS EXPRESSED OR IMPLIED BY THE DEVELOPERS OR THE DISTRIBUTORS ON THE ACCURACY OR THE RELIABILITY OF THE PROGRAM.

THIS PROGRAM IS A VERY PRACTICAL TOOL FOR THE DESIGN/CHECK OF CONCRETE STRUCTURES. HOWEVER, THE USER MUST THOROUGHLY READ THE MANUAL AND CLEARLY RECOGNIZE THE ASPECTS OF SHEAR WALL DESIGN THAT THE PROGRAM ALGORITHMS DO NOT ADDRESS.

THE USER MUST EXPLICITLY UNDERSTAND THE ASSUMPTIONS OF THE PROGRAM AND MUST INDEPENDENTLY VERIFY THE RESULTS.

Contents

General Shear Wall Design Information

1	**General Design Information**	
	Design Codes	1-1
	Units	1-1
	Defining Piers and Spandrels	1-2
	Wall Pier Labeling	1-2
	Assigning Wall Pier Labels	1-3
	Wall Spandrel Labeling	1-6
	Assigning Wall Spandrel Labels	1-6
	Wall Meshing and Gravity Loading	1-9
	Using Frame Elements to Model Spandrels	1-12
	Analysis Sections and Design Sections	1-12
	Design Station Locations	1-14
	Design Load Combinations	1-15
2	**Shear Wall Design Process**	
	Typical Design Process	2-1
3	**Output Data Plotted Directly on the Model**	
	Overview	3-1
	Design Input	3-2
	Material	3-2
	Pier Section Information	3-2
	Design Output	3-3
	Simplified Pier Longitudinal Reinforcing	3-3
	Simplified Pier Edge Members	3-3
	General Reinforcing and Uniform Reinforcing Pier Flexural Reinforcing Ratios	3-3
	General Reinforcing and Uniform Reinforcing Pier Flexural Demand/Capacity Ratios	3-4

Spandrel Longitudinal Reinforcing 3-4
Pier/Spandrel Shear Reinforcing 3-4
Spandrel Diagonal Shear Reinforcing 3-5
Pier Boundary Zones 3-5

4 Input Data
Using the Print Design Tables Form 4-1
Preferences 4-2
Input Summary 4-4

5 Output Data
Overview 5-1
Using the Print Design Tables Form 5-1
Output Summary 5-2

6 Wall Pier Design Sections
Simplified Pier Design Dimensions and Properties 6-1
Design Dimensions 6-1
How the Program Calculates the Default Dimensions 6-2
Material Properties 6-3
General Reinforcing Pier Section 6-3
Uniform Reinforcing Pier Seciton 6-4
Shear Design Dimensions for Uniform and General Reinforcing Pier Sections 6-4

7 Wall Spandrel Design Sections
Wall Spandrel Design Dimensions 7-1
Default Design Dimensions 7-2
Default Design Material Property 7-4

8 Define Pier Reinforcing Using Section Designer
Local Axes Definition and Orientation 8-1
Initial Definition of a Wall Pier Section 8-1
Creating a Pier Section from Scratch 8-3
Creating a Pier from the Geometry of an Existing Analysis Pier Section 8-3
Modifying the Geometry of the Concrete Section 8-3
Revising Rebar Size, Cover and Spacing 8-4

General 8-4
Methodology 8-5
Modifying Material Properties 8-6
Interaction Diagrams and Moment-Curvature Plots 8-6

Shear Wall Design Specific to UBC97

9 General and Notation
Introduction to the UBC 97 Series of Technical Notes 9-1
Notation 9-2

10 Interactive Design Output
Overview 10-1
Interactive Pier Design and Review 10-2
Design of a Simplified Section 10-2
Design of a Uniform Reinforcing or General Reinforcing Section 10-6
Check of a Uniform Reinforcing or General Reinforcing Section 10-9
Interactive Spandrel Design and Review 10-12
Command Buttons 10-16
Overwrites Button 10-16
Section Top and Section Bot Buttons 10-16

11 Preferences
General 11-1
Flags and Factors 11-3
Using the Preferences Form 11-4

12 Overwrites
General 12-1
Pier Design Overwrites 12-2
LL Reduction Factor 12-7
EQ Factor 12-8
User-Defined Edge Members 12-9
Spandrel Design Overwrites 12-9
Making Changes in the Overwrites Form 12-12

13 Design Load Combinations

Default Design Load Combinations 13-1

Dead Load Component 13-2

Live Load Component 13-2

Wind Load Component 13-2

Earthquake Load Component 13-2

Design Load Combinations that Include a Response Spectrum 13-3

Design Load Combinations that Include Time History Results 13-4

Design Load Combinations that Include Static Nonlinear Results 13-5

14 Wall Pier Flexural Design

Overview 14-1

Designing a Simplified Pier Section 14-1

Design Condition 1 14-2

Design Condition 2 14-6

Design Condition 3 14-6

Checking a General or Uniform Reinforcing Pier Section 14-6

Interaction Surface 14-6

Designing a General Reinforcing Pier Section 14-17

15 Wall Pier Shear Design

General 15-1

Determine the Concrete Shear Capacity 15-2

Determine the Required Shear Reinforcing 15-3

Seismic and Nonseismic Piers 15-3

Additional Requirements for Seismic Piers 15-3

16 Spandrel Flexural Design

General 16-1

Determine the Maximum Factored Moments 16-1

Determine the Required Flexural Reinforcing 16-2

Rectangular Beam Flexural Reinforcing 16-3

T-Beam Flexural Reinforcing 16-6

17 Spandrel Shear Design

General 17-1
Determine the Concrete Shear Capacity 17-2
Determine the Required Shear Reinforcing 17-2
Seismic and Nonseismic Spandrels 17-3
Seismic Spandrels Only 17-5

18 Wall Pier Boundary Elements

Details of Check for Boundary Element Requirements 18-1
Example 18-5

19 Input Data

General 19-1
Using the Print Shear Wall Design Tables Form 19-1
Summary Input Data 19-2
Design Preferences Input Data 19-4

20 Output Details

Simplified Pier Section Design 20-2
Section Designer Pier Section Design 20-8
Section Designer Pier Section Check 20-14
Spandrel Design 20-19

Shear Wall Design Specific to ACI-318-99

21 General and Notation

Introduction to the ACI318-99 Series of Technical Notes 21-1
Notation 21-2

22 Interactive Design Output

Overview 22-1
Interactive Pier Design and Review 22-2
Design of a Simplified Section 22-2
Design of a Uniform Reinforcing or General Reinforcing Section 22-6
Check of a Uniform Reinforcing or General Reinforc- 22-9

ing Section
Interactive Spandrel Design and Review 22-12
Command Buttons 22-16
Combos Button 22-16
Overwrites Button 22-16
Section Top and Section Bot Buttons 22-16

23 Preferences
General 23-1
Flags and Factors 23-3
Using the Preferences Form 23-4

24 Overwrites
General 24-1
Pier Design Overwrites 24-2
LL Reduction Factor 24-7
EQ Factor 24-8
User-Defined Edge Members 24-9
Spandrel Design Overwrites 24-9
Making Changes in the Overwrites Form 24-12

25 Design Load Combinations
Default Design Load Combinations 25-1
Dead Load Component 25-2
Live Load Component 25-2
Wind Load Component 25-2
Earthquake Load Component 25-2
Design Load Combinations that Include a Response Spectrum 25-3
Design Load Combinations that Include Time History Results 25-4
Design Load Combinations that Include Static Nonlinear Results 25-5

26 Wall Pier Flexural Design
Overview 26-1
Designing a Simplified Pier Section 26-1
Design Condition 1 26-2
Design Condition 2 26-6

Design Condition 3 26-6
Checking a General or Uniform Reinforcing Pier Section 26-6
Interaction Surface 26-6
Designing a Section Designer Pier Section 26-17

27 Wall Pier Shear Design
General 27-1
Determine the Concrete Shear Capacity 27-2
Determine the Required Shear Reinforcing 27-3
Seismic and Nonseismic Piers 27-3
Additional Requirements for Seismic Piers 27-3

28 Spandrel Flexural Design
General 28-1
Determine the Maximum Factored Moments 28-1
Determine the Required Flexural Reinforcing 28-2
Rectangular Beam Flexural Reinforcing 28-3
T-Beam Flexural Reinforcing 28-6

29 Spandrel Shear Design
General 29-1
Determine the Concrete Shear Capacity 29-2
Determine the Required Shear Reinforcing 29-2
Seismic and Nonseismic Spandrels 29-2
Seismic Spandrels Only 29-5

30 Wall Pier Boundary Elements
Details of Check for Boundary Element Requirements 30-1
Example 30-5

31 Input Data
General 31-1
Using the Print Shear Wall Design Tables Form 31-1
Summary Input Data 31-2
Design Preferences Input Data 31-4

32 Output Details
Simplified Pier Section Design 32-2
Section Designer Pier Section Design 32-8
Section Designer Pier Section Check 32-14
Spandrel Design 32-19

Technical Note 1
General Design Information

This Technical Note presents some basic information and concepts related to designing and checking shear walls using this program.

Design Codes

The design code is set using the **Options menu > Preferences > Shear Wall Design** command. You can choose to design for any one design code in any one design run. You cannot design some beams for one code and others for a different code in the same design run. You can however perform different design runs using different design codes without rerunning the analysis.

Units

For shear wall design in this program, any set of consistent units can be used for input. Also, the system of units being used can be changed at any time. Typically, design codes are based on one specific set of units.

The shear wall design preferences allow the user to specify special units for concentrated and distributed areas of reinforcing. These units are then used for reinforcing in the model, regardless of the current model units displayed in the drop-down box on the status bar (or within a specific form). The special units specified for concentrated and distributed areas of reinforcing can only be changed in the shear wall design preferences.

The choices available in the shear wall design preferences for the units associated with an area of concentrated reinforcing are in^2, cm^2, mm^2, and current units. The choices available for the units associated with an area per unit length of distributed reinforcing are in^2/ft, cm^2/m. mm^2/m, and current units.

The current units option uses whatever units are currently displayed in the drop-down box on the status bar (or within a specific form). If the current length units are feet, this option means concentrated areas of reinforcing are in ft^2 and distributed areas of reinforcing are in ft^2/ft. Note that when using the "current" option, areas of distributed reinforcing are specified in Length^2/Length units, where Length is the currently active length unit. For example, if you are working in kip and feet units, the area of distributed reinforcing is specified in ft^2/ft. If you are in kips and inches, the area of distributed reinforcing is specified in in^2/in.

Defining Piers and Spandrels

Define piers and spandrels by assigning them labels.

Tip:

You must assign a pier or spandrel element a label before you can get output forces for the element or before you can design the element.

Pier labels are assigned to vertical area objects (walls) and to vertical line objects (columns). Objects that are associated with the same story level and have the same pier label are considered to be part of the same pier.

> ***Important note:*** Do not confuse pier labels with the names of pier sections that are defined in Section Designer and assigned to General Reinforcing piers. The pier labels are used to define/identify the pier. All piers have a pier label. General reinforcing pier sections are section properties of the pier.

Spandrel labels are assigned to vertical area objects (walls) and to horizontal line objects (beams). Unlike pier elements, a single wall spandrel element can be made up of objects from two (or more) adjacent story levels.

Wall Pier Labeling

Wall pier forces are output at the top and bottom of wall pier elements. Also, wall pier design is only performed at stations located at the top and bottom of wall pier elements.

Each area object that makes up a part of a wall may be assigned one pier label (and one spandrel label). You cannot assign a single area object multiple wall pier labels. Area objects at the same story level with the same pier label are assumed by the program to be part of the same pier.

Wall pier labels are used to identify wall piers. After a wall pier has been assigned a label and an analysis has been run, forces can be output for the wall pier and it can be designed.

A single wall pier cannot extend over multiple stories. It must be fully contained within one story level.

Assigning Wall Pier Labels

Figure 1 illustrates some possible wall pier labeling arrangements for a two-story wall. Note that the layout of the wall is similar at the two levels, except that at the upper level, the pier to the left of the door opening is broken into two area objects.

Figure 1a shows a common way to label piers. At the upper level, Pier P1 is defined to extend all the way across the wall above the openings. Pier P2 makes up the wall pier to the left of the door opening. Pier P3 occurs between the door and window openings. Pier P4 occurs between the window opening and the edge of the wall. Pier P5 occurs below the window opening between the door and the edge of the wall. A similar labeling of piers occurs at the lower level.

Note the following about the wall pier labeling scheme shown in Figure 1a:

- Wall piers are always associated with the story level directly above them. Thus, in Figure 1a, the upper level wall piers are associated with the Roof level and the lower level wall piers are associated with the 2nd level. Because the wall piers are associated with story levels, wall pier labels can repeat at different levels, as shown in the figure.

- When we refer to wall pier P1 at the Roof level in Figure 1a, we are referring to the pier across the entire width of the wall that is made up of the five area objects given the pier label P1. Similarly, pier P2 at the Roof level is made up of the two area objects to the left of the door opening.

- Wall pier design is performed at the top and bottom of each pier. Thus, for wall pier P2 at the Roof level, design is performed at the top and bottom of the door opening. No design is performed near the midheight of the door opening because the design is done at the top and bottom of the wall pier, not the top and bottom of each area object that makes up the wall pier.

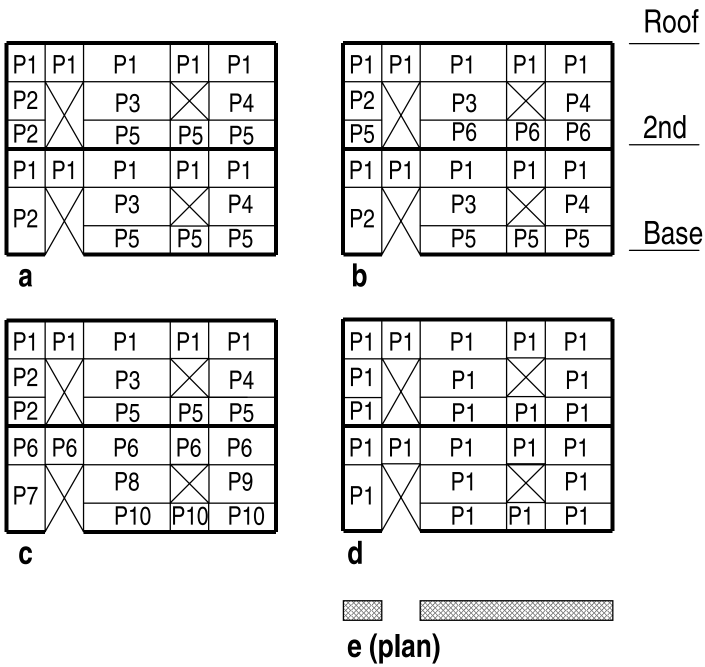


Figure 1 Examples of Wall Pier Labeling

- Wall pier forces are reported at the top and bottom of each pier. Thus, for wall pier P2 at the Roof level, wall pier forces are reported (printed) for locations at the top and bottom of the door opening. For graphic representation on the model, the forces are plotted at the top and bottom of the pier and connected with a straight line.
- If, for example, you are not interested in either design or output forces for wall piers P1 and P5 at the Roof level, do not provide wall pier labels for those area objects.

Note:

Wall piers are always associated with the story level directly above them.

Figure 1b shows a design section near the midheight of the Roof level pier on the left side of a door opening. Notice that the two area objects are given different pier labels, P2 and P5.

Figure 1c illustrates that pier numbers do not have to be repeated at each level. Each wall pier can be given a unique label. Even with unique names, the piers are still associated with story levels. For example, in Figure 1c, pier P7 is associated with the 2nd level.

Figure 1d illustrates that all of the area objects can be given the same label; P1 in this case. For this condition, wall design would be performed across the entire wall at each story level (i.e., the top and bottom of each pier), and wall forces would be provided for the entire wall at each story level.

Tip:

If you need to mesh an existing area object to define a wall pier, you can select the area object(s) and use the **Edit menu > Mesh Areas** command.

In Figure 1d, the design of the bottom of the lower level pier is based on the section shown in Figure 1e. The program would assume that the two areas that comprise these sections are rigidly connected.

In contrast to the example shown in Figure 1, pier labels can be specified for only some of the area objects in the wall, as shown in Figure 2. Design for the Figure 2 example would not capture the overall effects at the top and bottom of each story level as would be the case if the piers were defined as shown in Figure 1. Thus, in general, to design the wall, we recommend that you define the piers as shown in Figure 1. Although defining the piers as shown in Figure 2 is acceptable, such a design my not yield all of the needed information.

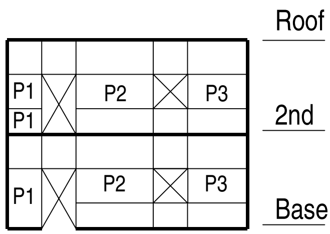


Figure 2: Example of Possibly Incomplete Wall Pier Labeling

Wall Spandrel Labeling

Wall spandrel forces are output at the left and right ends of wall spandrel elements. Also, wall spandrel design is only performed at stations located at the left and right ends of wall spandrel elements.

Each area object that makes up a part of a wall may be assigned one spandrel label (and one pier label). Multiple wall spandrel labels cannot be assigned to a single area object.

Wall spandrel labels are used to identify wall spandrels. After a wall spandrel has been assigned a label and an analysis has been run, forces can be output for the wall spandrel and it can be designed.

Assigning Wall Spandrel Labels

Figure 3 illustrates some possible wall spandrel labeling arrangements for a two-story wall. Note that this is the same two-story wall illustrated in Figure 1 for the description of wall pier labeling.

Figure 3a shows possibly the most common condition for wall spandrel labeling. Note the following about the wall spandrel labeling scheme shown in Figure 3a:

- Unlike wall pier elements, a single wall spandrel element can include area objects from two adjacent story levels. Use the following method to determine the association between the story level and the pier spandrel.

  - ✓ Start with the upper-most area object in the spandrel. Check if the top of the object is at a story level. If it is, this is the story associated with the spandrel. If it is not, check if the bottom of the area object is at a story level. If it is, this is the story associated with the spandrel.

  - ✓ If the previous process does not locate a story level, continue downward to the next highest area object and check for story levels at the top or bottom of the object.

  - ✓ Continue the process until a level is located. Thus, a spandrel is typically associated with the highest story level that it touches or intersects.

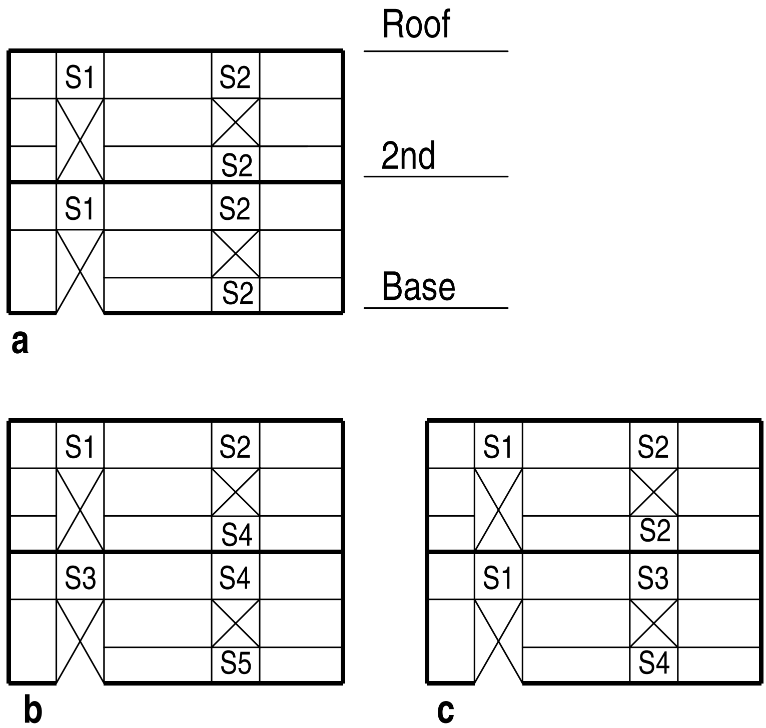


Figure 3: Examples of Wall Spandrel Labeling

- ✓ If the spandrel does not actually touch or intersect a story level, it is associated with the story level just above it. An example of this is described later.

Tip:

If you need to mesh an existing area object to define a wall spandrel, you can select the area object(s) and use the **Edit menu > Mesh Areas** command.

- In Figure 3a, the upper wall spandrel label S1 is associated with the Roof level and the lower S1 is associated with the 2nd level. The upper wall spandrel label S2 is associated with the Roof level, the middle spandrel made up of two area objects labeled S2 is associated with the 2nd level, and the lowest S2 spandrel is associated with the Base level.

- Because the wall spandrels are associated with story levels, wall spandrel labels can be repeated at different levels, as shown in the Figure 3.

- When we refer to wall spandrel S2 at the 2nd level in Figure 3a, we are referring to the spandrel that is made up of the two area objects given the spandrel label S2.

- Wall spandrel design is performed at the left and right sides of each spandrel. Thus, for wall spandrel S1 at the Roof level, design is performed at the left and right sides of the door opening.

- Wall spandrel forces are reported at the left and right sides of each spandrel. Thus, for wall spandrel S1 at the Roof level, wall spandrel forces are reported (printed) for locations at the left and right sides of the door opening. For graphic representation on the model, the forces are plotted at the left and right sides of the spandrel and connected with a straight line.

- If you are not interested in either design or output forces for certain wall spandrels, do not provide wall spandrel labels for those area objects.

Figure 3b illustrates that spandrel numbers do not have to be repeated at each level. Each wall spandrel can be given a unique label. Even with unique names, the spandrels are still associated with story levels. For example, in Figure 3b, spandrel S4 is associated with the 2nd level.

Figure 3c illustrates a condition that the program will accept, although it is doubtful that you would want to label the spandrels as shown. Specifically, refer to the spandrel at the 2nd level between the windows. Notice that the upper area object for this spandrel is labeled S2 and the lower area object is labeled S3. The program will accept this and will design the two objects as separate spandrels.

In the 3-story structure shown in Figure 4, the top spandrel labeled S1 is associated with the Roof level. The middle S1 spandrel is associated with the 3rd level, which is the highest story level that it intersects or touches. The lowest S1 spandrel is associated with the Base level.

In the 1-story structure shown in Figure 4, the top spandrel labeled S1 is associated with the Roof level. The middle spandrel labeled S2 is also associated with the Roof level because the spandrel does not intersect or touch any story levels and thus it is associated with the story level directly above it. The lowest S1 spandrel is associated with the Base level.

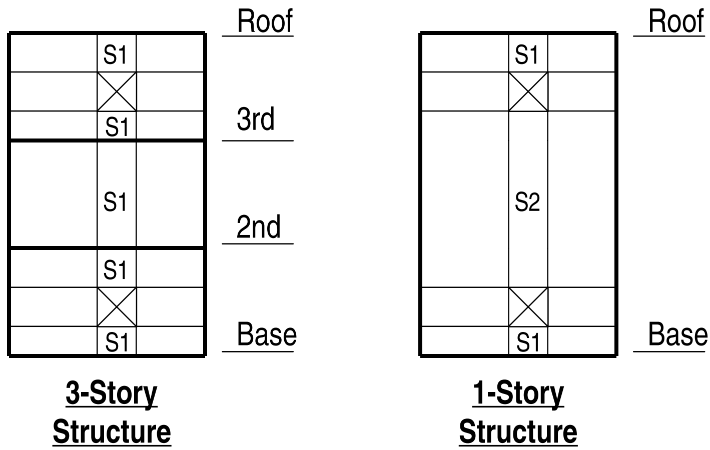


Figure 4: Additional Examples of Wall Spandrel Labeling

Wall Meshing and Vertical Loading

You must manually mesh the walls in your model. No automatic wall meshing is available in the program. The meshing tools are available on the Edit Menu. This section provides a few comments about wall meshing.

It is important to understand that loads are only transferred to walls at the corner points of the area objects that make up the wall. Consider the example shown in Figure 5a, which illustrates the load transfer associated with a floor deck connecting to a wall. The transfer of load only occurs at the joints (corner points) of the area objects.

Figure 5b illustrates the loads that are transferred to the wall as P1, P2, P3 and P4. These loads are obtained as follows.

- Load P1 comes from the end reaction of Beam 1 and from the uniform load in the floor area labeled 1.
- Load P2 comes from the uniform load in the floor area labeled 2.
- Load P3 comes from the uniform load in the floor area labeled 3.

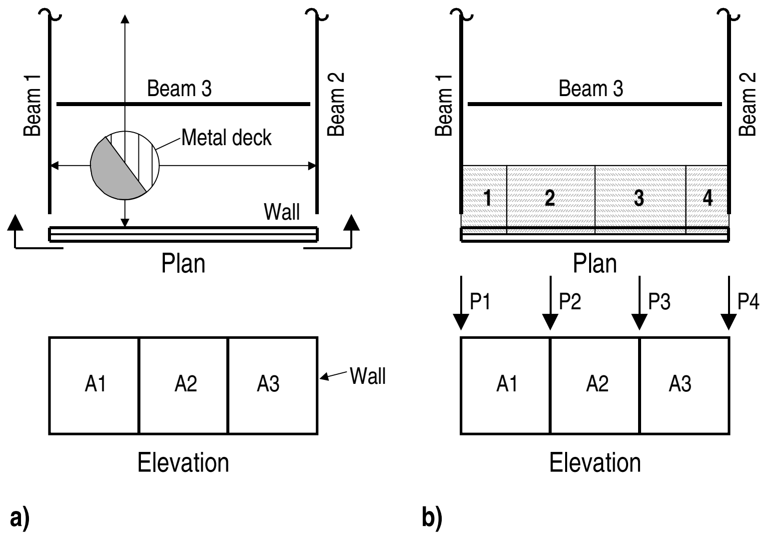


Figure 5: Example of Floor Deck Connecting to a Wall

- Load P4 comes from the end reaction of Beam 2 and from the uniform load in the floor area labeled 1.

Thus, the uniform floor load is not transferred to the wall as a uniform load. Instead, it transfers as a series of point loads. The point loads are located at the corner points of the area objects that make up the wall.

Consider Figure 6, which shows three types of deformation that a single shell element could experience. A single shell element in the program captures shear and axial deformations well. A single shell element is unable to capture bending deformation. Thus, in piers and spandrels where bending deformations are significant (skinny piers and spandrels), you may want to mesh the pier or spandrel into several elements.

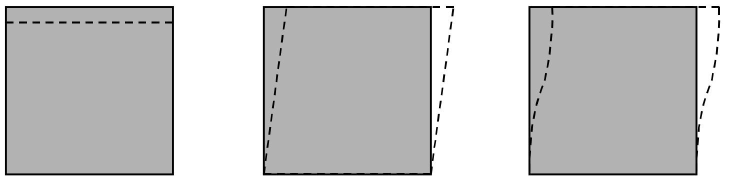
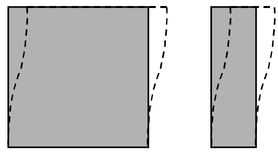


Figure 6: Shell Element Deformation



For example, consider the shell elements shown in the sketch to the right. Bending deformations in shell "a" are probably insignificant and thus no further meshing is needed. The bending deformations in shell "b" may be significant and thus you may want to mesh it into additional shell elements.

Now consider the wall shown in Figure 7. Figure 7a shows the wall modeled with five shell elements. Because the aspect ratio of the shell elements is good—that is, they are not long and skinny—bending deformations should not be significant, and thus, no further meshing of the wall is necessary to accurately capture the results.

Figure 7b shows the same wall with the opening shifted to the left, such that the left pier becomes skinny. In this case, bending deformations may be significant in that pier, and thus, it is meshed into two shell elements.

Figure 7c shows the same wall with the opening made taller, such that the spandrel beam becomes skinny. In this case, bending deformations may be significant in the spandrel, and thus, it is meshed into four shell elements. Meshing it into four elements rather than two helps it to better capture the gravity load bending. As the spandrel becomes skinnier, you may want to use a frame element to model it.

No specific rule exists to determine when to mesh a pier or spandrel element into additional shell elements to adequately capture bending deformation. It is really best addressed by doing comparative analyses with and without the additional meshing and applying some engineering judgment. Nevertheless, we suggest that if the aspect ratio of a pier or spandrel that is modeled with

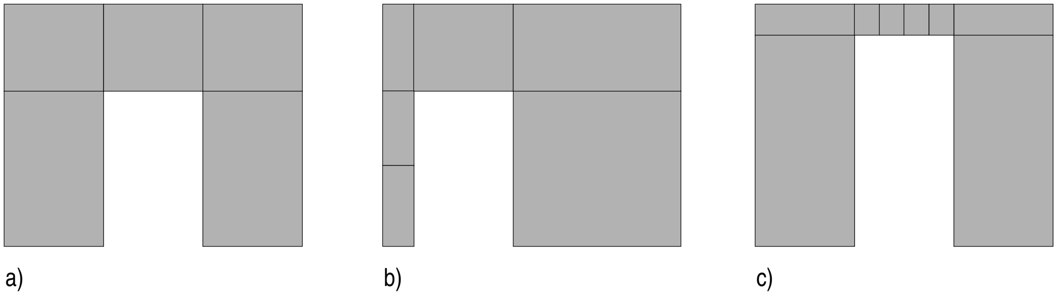


Figure 7: Shell Element Meshing Example for Piers and Spandrels

one shell element is worse than 3 to 1, consider additional meshing of the element to adequately capture the bending deformation.

Using Frame Elements to Model Spandrels

When using a frame element (beam) to model a shear wall spandrel, keep in mind that the analysis results obtained are dependent on the fixity provided by the shell element that the beam connects to. Different sized shell elements provide different fixities and thus, different analysis results.

In general, for models where the spandrels are modeled using frame elements, better analysis results are obtained when a coarser shell element mesh is used; that is, when the shell elements that the beam connects to are larger. If the shell element mesh is refined, consider extending the beam into the wall at least one shell element to model proper fixity.

If the depth of the shell element approaches the depth of the beam, consider either extending the beam into the wall as mentioned above, or modeling the spandrel with shell elements instead of a frame element.

Analysis Sections and Design Sections

It is important to understand the difference between analysis sections and design sections when performing shear wall design. Analysis sections are simply the objects defined in your model that make up the pier or spandrel section. The analysis section for wall piers is the assemblage of wall and column sections that make up the pier. Similarly, the analysis section for spandrels is the assemblage of wall and beam sections that make up the spandrel.

The analysis is based on these section properties, and thus, the design forces are based on these analysis section properties.

In general, the design section is completely separate from the analysis section. Three types of pier design sections are available. They are:

- **Uniform Reinforcing Section:** For flexural designs and/or checks, the program automatically (and internally) creates a Section Designer pier section of the same shape as the analysis section pier. Uniform reinforcing is placed in this pier. The reinforcing can be modified in the pier overwrites. The Uniform Reinforcing Section pier may be planar or it may be three-dimensional.

  For shear design and boundary zone checks, the program automatically (and internally) breaks the analysis section pier up into planar legs and then performs the design on each leg separately and reports the results separately for each leg. Note that the planar legs are derived from the area objects defined in the model, not from the pier section defined in Section Designer. The pier section defined in Section Designer is only used for the flexural design/check.

- **General Reinforcing Section:** For flexural designs and/or checks, the pier geometry and the reinforcing is defined by the user in the Section Designer utility. The pier defined in Section Designer may be planar or it may be three-dimensional.

  For shear design and boundary zone checks, the program automatically (and internally) breaks the analysis section pier up into planar legs and then performs the design on each leg separately and reports the results separately for each leg. Note that the planar legs are derived from the area objects defined in the model, not from the pier section defined in Section Designer. The pier section defined in Section Designer is only used for the flexural design/check.

- **Simplified Pier Section:** This pier section is defined in the pier design overwrites. The simplified section is defined by a length and a thickness. The length is in the pier 2-axis direction and the thickness is in the pier 3-axis direction.

In addition, you can, if desired, specify thickened edge members at one or both ends of the simplified pier section. You cannot specify reinforcing in a simplified section. Thus, the simplified section can only be used for design, not for checking user-specified sections. Simplified sections are always planar.

See Shear Wall Design Technical Note 6 Wall Pier Design Sections for a detailed description of pier design sections.

Only one type of spandrel design section is available. It is defined in the spandrel design overwrites. A typical spandrel is defined by a depth, thickness and length. The depth is in the spandrel 2-axis direction; the thickness is in the spandrel 3-axis direction; and the length is in the spandrel 1-axis direction. Spandrel sections are always planar.

In addition, you can, if desired, specify a slab thickness and depth, making the spandrel design section into a T-beam. You cannot specify reinforcing in a spandrel section. Thus, you can only design spandrel sections, not check them.

See Shear Wall Design Technical Note 7 Wall Spandrel Design Sections for a detailed description of spandrel design sections.

The pier and spandrel design sections are designed for the forces obtained from the program's analysis, which is based on the analysis sections. In other words, the design sections are designed based on the forces obtained for the analysis sections.

Design Station Locations

The program designs wall piers at stations located at the top and bottom of the pier only. To design at the mid-height of a pier, break the pier into two separate "half-height" piers.

The program designs wall spandrels at stations located at the left and right ends of the spandrel only. To design at the mid-length of a spandrel, break the spandrel into two separate "half-length" piers. Note that if you break a spandrel into pieces, the program will calculate the seismic diagonal shear reinforcing separately for each piece. The angle used to calculate the seismic diagonal shear reinforcing for each piece is based on the length of the piece, not the length of the entire spandrel. This can cause the required area of diagonal reinforcing to be significantly underestimated. *Thus, if you break a spandrel into pieces, calculate the seismic diagonal shear reinforcing separately by hand.*

Design Load Combinations

The program creates a number of default design load combinations for shear wall design. You can add in your own design load combinations. You can also modify or delete the program default load combinations. An unlimited number of design load combinations can be specified.

To define a design load combination, simply specify one or more load cases, each with its own scale factor. See Shear Wall Design UBC97 Technical Note 13 Design Load Combinations and Shear Wall Design UBC97 Technical Note 24 Design Load Combinations for more information with respect to code-specific design load combinations.

SHEAR WALL DESIGN

Technical Note 2
Shear Wall Design Process

This Technical Note describes a typical shear wall design processes for a new building. Although the exact steps you follow may vary, the basic processes should be similar to those described herein.

Typical Design Process

1. Use the **Options menu > Preferences > Shear Wall Design** command to review the shear wall design preferences and revise them if necessary. Note that default values are provided for all shear wall design preferences so it is unnecessary to define any preferences unless you want to change some of the default values. See Shear Wall Design UBC97 Technical Note 11 Preferences and Shear Wall Design ACI318-99 Technical Note 22 Preferences for more information.

2. Create the building model.

3. Assign the wall pier and wall spandrel labels using the **Assign menu > Frame/Line > Pier Label**, the **Assign menu > Shell/Area > Pier Label**, the **Assign menu > Frame/Line > Spandrel Label**, and the **Assign menu > Shell/Area > Spandrel Label** commands. Refer to Shear Wall Design Technical Note 1 General Design Information for additional information on pier and spandrel labeling.

4. Run the building analysis using the **Analyze menu > Run Analysis** command.

5. Assign shear wall overwrites, if needed, using the **Design menu > Shear Wall Design > View/Revise Pier Overwrites** and the **Design menu > Shear Wall Design > View/Revise Spandrel Overwrites** commands. Note that piers or spandrels must be selected before using these commands. Also note that default values are provided for all pier and spandrel design overwrites so it is unnecessary to define any overwrites unless you want to change some of the default values. Note that the overwrites can

be assigned before or after the analysis is run. See Shear Wall Design UBC97 Technical Note 12 Overwrites and Shear Wall Design ACI318-99 Technical Note 23 Overwrites for more information.

We recommend that you initially design the pier using the Uniform Reinforcing pier section type. This is the default setting for all piers. You may want to modify the default values for edge bar size and spacing and end/corner bar size. Initially we recommend that you set the Check/Design Reinforcing option to Design.

Important note about selecting piers and spandrels: Select a pier or spandrel simply by selecting any line or area object that is part of the pier or spandrel. The **Set Building View Options** button on the top toolbar or its associated **View menu > Set Building, View Options** command, can be helpful in displaying piers and spandrels.

6. To use any design load combinations other than the defaults created by the program for your shear wall design, click the **Design menu > Shear Wall Design > Select Design Combo** command. Note that design combos must have already been created by clicking the **Define menu > Load Combinations** command. See Shear Wall Design UBC97 Technical Note 13 Design Load Combinations and Shear Wall Design ACI318-99 Technical Note 24 Design Load Combinations for more information.

7. Click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command to run the shear wall design.

8. Review the shear wall design results by doing one of the following:

    a. Click the **Design menu > Shear Wall Design > Display Design Info** command to display design input and output information on the model. See Shear Wall Design Technical Note 3 Output Data Plotted Directly on the Model for more information.

    b. Right click on a pier or spandrel while the design results are displayed on it to enter the interactive wall design mode. Note that while you are in this mode, you can revise overwrites and immediately see the new design results.

If design results are not currently displayed (and the design has been run), click the **Design menu > Shear Wall Design > Interactive Wall Design** command and then right click a pier or spandrel to enter the interactive design mode for that element.

c. Use the **File menu > Print Tables > Shear Wall Design** command to print shear wall design data. If you select piers or spandrels before using this command, data is printed only for the selected elements. See Shear Wall Design Technical Note 4 Printed Input Data and Shear Wall Design Technical Note 5 Printed Design Output Data for more information.

9. If desired, revise the wall pier and/or spandrel overwrites, rerun the shear wall design, and review the results again. Repeat this process as many times as needed.

10. Create wall pier design sections with actual pier geometry and rebar placement specified for the wall piers using the Section Designer utility (see Shear Wall Design Technical Note 8 Define Pier Reinforcing Using Section Designer for more information). Use the **Design menu > Shear Wall Design > Define General Pier Sections** command to define the sections in Section Designer. In the overwrites change the pier design type to General Reinforcing and specify the pier sections at the top and bottom of the pier. Leave the Check/Design Reinforcing option set to Design.

    Note that at this point, since we are designing the pier, not checking it, the actual bar size specified in the Section Designer pier sections is not important. However, the relative bar size is important; that is, the size of one rebar in the pier section relative to the other bars in the section. For design, the program always maintains this relationship.

11. Run the shear wall design, and review the results. If necessary, revise the pier and repeat this process as many times as needed.

12. Modify the Section Designer wall pier sections to reflect the actual desired reinforcing bar location and sizes. Use the **Design menu > Shear Wall Design > Define General Pier Sections** command to modify the sections in Section Designer. Be sure to indicate that the reinforcing is to be

checked (not designed) in the Pier Section Data form. Rerun the design and verify that the actual flexural reinforcing provided is adequate.

13. If necessary, revise the geometry or reinforcing in the Section Designer section and rerun the design check.

14. Print or display selected shear wall design results if desired. See Shear Wall Technical Note 4 Input Data and Shear Wall Technical 5 Output Data for more information.

Note that shear wall design is performed as an iterative process. You can change your wall design dimensions and reinforcing during the design process without rerunning the analysis.

See these Technical Notes for more information:

Shear Wall Design Technical Note 7 Wall Pier Design Sections.

Shear Wall Design Technical Note 8 Wall Spandrel Design Sections.

Shear Wall Design UBC 97 Technical Note 14 Wall Pier Flexural Design and Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design.

Shear Wall Design UBC 97 Technical Note 15 Wall Pier Shear Design and Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Shear Design.

Shear Wall Design UBC 97 Technical Note 16 Spandrel Flexural Design and Shear Wall Design ACI318-99 Technical Note 27 Spandrel Flexural Design.

Shear Wall Design UBC 97 Technical Note 17 Spandrel Shear Design and Shear Wall Design ACI318-99 Technical Note 28 Spandrel Shear Design.

Shear Wall Design UBC 97 Technical Note 18 Wall Pier Boundary Elements and Shear Wall Design ACI318-99 Technical Note 29 Wall Pier Boundary Elements.

Technical Note 3
Output Data Plotted Directly on the Model

This Technical Note describes the output data that can be plotted directly on the model.

Overview

Use the **Design menu > Shear Wall Design > Display Design Info** command to display on-screen output plotted directly on the model. If desired, the screen graphics can then be printed using the **File menu > Print Graphics** command. The on-screen display data is organized into two main groups, as follows.

- Design Input
  - ✓ Material
  - ✓ Pier section information
- Design Output
  - ✓ Simplified pier longitudinal reinforcing
  - ✓ Simplified pier edge members
  - ✓ General reinforcing and uniform reinforcing pier flexural reinforcing ratios
  - ✓ General reinforcing and uniform reinforcing pier flexural D/C ratios
  - ✓ Spandrel longitudinal reinforcing
  - ✓ Pier and spandrel shear reinforcing
  - ✓ Spandrel diagonal shear reinforcing
  - ✓ Pier boundary zones

Note that you cannot display more than one of the listed items on the model at the same time. Each of these items is described in more detail in subsequent sections of this Technical Note.

The output plotted directly on piers is plotted along an invisible line that extends from the centroid of the pier section at the bottom of the pier to the centroid of the pier section at the top of the pier. Similarly, the output plotted directly on spandrels is plotted along an invisible line that extends from the centroid of the spandrel section at the left end of the spandrel to the centroid of the spandrel section at the top of the spandrel.

Design Input

Material

Displaying the material data provides the following:

- For simplified pier sections and uniform reinforcing pier sections, the material property for the section, which is specified in the pier overwrites.

- For general reinforcing pier sections, the base material property for the section. The base material is specified in the Pier Section Data form that is accessed by clicking the **Design menu > Shear Wall Design > Define General Pier Sections** command, and clicking the **Add Pier Section** button or the **Modify/Show Pier Section** button.

- For spandrels, the material property for the section, which is specified in the spandrel overwrites.

Separate material properties are specified at the top and bottom of all pier sections. A single material property is displayed for spandrel sections.

Pier Section Information

Displaying the material data provides the following:

- For uniform reinforcing pier sections, the edge bar size and spacing followed by either a (D) for design or (C) for check are displayed on the top line. The end/corner bar size and clear cover are displayed on the bottom line.

- For general reinforcing pier sections, the Section Designer pier section name followed by either a (D) for design or (C) for check are displayed at the top and bottom of the pier.
- For simplified pier sections, a note identifying the pier as a simple section is displayed.

Design Output

Simplified Pier Longitudinal Reinforcing

Displaying the simplified pier longitudinal reinforcing data provides the maximum required area of concentrated reinforcing in the left and right edge members. Reinforcing areas are shown at the top and bottom of the pier. Data is not displayed for piers that are assigned general reinforcing and uniform reinforcing sections.

Simplified Pier Edge Members

Displaying the simplified pier edge member data provides either the user-defined edge member length (DB1 dimension) or the program-determined edge member length at the left and right ends of the pier. Edge member lengths are shown at the top and bottom of the pier. Data is not displayed for piers that are assigned general reinforcing and uniform reinforcing sections.

Note that if you defined an edge member length (DB1 dimension) in the pier design overwrites, the program uses that length in the design and it reports the length here. See "Designing a Simplified Pier Section" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design and in Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design for more information.

General Reinforcing and Uniform Reinforcing Pier Flexural Reinforcing Ratios

Displaying the pier flexural reinforcing ratios provides the maximum required reinforcing ratio at the top and bottom of all piers that are assigned general reinforcing or uniform reinforcing sections and are designated to be designed.

The reinforcing ratio is equal to the total area of vertical steel in the pier divided by area of the pier. The required reinforcing is assumed to be provided in the same proportions as specified in the pier section.

Only two ratios are reported, one at the top of the pier and one at the bottom of the pier. This is true whether the pier is considered two-dimensional or three-dimensional. For two-dimensional piers, the ratio is based on the P-M3 interaction. For three-dimensional piers, the ratio is based on the P-M2-M3 interaction.

General Reinforcing and Uniform Reinforcing Pier Flexural Demand/Capacity Ratios

Displaying the pier demand/capacity ratios provides the maximum demand/capacity ratio at the top and bottom of all piers that are assigned general reinforcing or uniform reinforcing sections and are designated to be checked. See the "Wall Pier Demand/Capacity Ratio" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design and in Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design for information on how the program calculates the demand/capacity ratio.

Only two demand/capacity ratios are reported, one at the top of the pier and one at the bottom of the pier. This is true whether the pier is considered two-dimensional or three-dimensional. For two-dimensional piers, the ratio is based on the P-M3 interaction. For three-dimensional piers, the ratio is based on the P-M2-M3 interaction.

Spandrel Longitudinal Reinforcing

Displaying the spandrel longitudinal reinforcing data provides the maximum required area of concentrated reinforcing in the top and bottom of the spandrel. Reinforcing areas are shown for the left and right sides of the spandrel.

Note:

Shear reinforcing is displayed for all piers and spandrels simultaneously.

Pier/Spandrel Shear Reinforcing

Displaying the shear reinforcing data provides the maximum required area of shear reinforcing for both piers and spandrels. For piers, shear reinforcing areas are displayed for both the top and the bottom of the piers.

Important Note: For piers with multiple legs, the shear reinforcing is reported for the worst-case leg.

For spandrel shear reinforcing, two types of shear reinforcing are displayed:

- **Distributed vertical shear reinforcement** is reported on the top line for the left and right ends of the beam.

- **Distributed horizontal shear reinforcement** is reported on the bottom line for the left and right ends of the beam.

Spandrel Diagonal Shear Reinforcing

In this case, the total area of a single leg of diagonal shear reinforcement is reported at each end of the spandrel. This steel is only calculated if the Design Type for the spandrel is seismic.

Pier Boundary Zones

This item applies only to codes that consider boundary zones. This is a required length, such as 22.762 inches, or it is "N/N," or it is "N/C." N/N indicates that boundary elements are not required. N/C means that no check for boundary elements is performed by the program.

Important Note: For piers with multiple legs the boundary zone requirement is reported for the worst-case leg. In addition, items such as the following are displayed:

TOP: 0 NC, 1 NN, 2N

BOT: 0 NC, 3 NN, 0N

These are summaries of the boundary zone requirements for the legs at the top and bottom of the pier. Here NC means Not Checked, NN means Not Needed and N means Needed.

See Shear Wall Design UBC 97 Technical Note 18 Wall Pier Boundary Elements and Shear Wall Design ACI318-99 Technical Note 29 Wall Pier Boundary Elements for more information.

Technical Note 4
Input Data

This Technical Note describes the printed design input data for shear wall design. It includes a description of the printout for the shear wall design preferences and for the shear wall input summary.

Using the Print Design Tables Form

To print wall pier/spandrel design preferences or the input summary directly to a printer, use the **File menu > Print Tables > Shear Wall Design** command and click the check box on the Print Design Tables form next to the desired type(s) of input data. Click the **OK** button to send the print to your printer. Click the **Cancel** button rather than the **OK** button to cancel the print.

Use the **File menu > Print Setup** command and the **Setup>>** button to change printers, if necessary.

To print wall pier/spandrel design preferences or the input summary to a file, click the Print to File check box on the Print Design Tables form. Click the **Filename>>** button to change the path or filename. Use the appropriate file extension for the desired format (e.g., .txt, .xls, .doc). Click the **OK** buttons on the Open File for Printing Tables form and the Print Composite Beam Design Tables form to complete the request.

Note:

The **File menu > Display Input/Output Text Files** command is useful for displaying output that is printed to a text file.

The Append check box allows you to add data to an existing file. The path and filename of the current file is displayed in the box near the bottom of the Print Design Tables form. Data will be added to this file. Or use the **Filename** button to locate another file, and when the Open File for Printing Tables caution box appears, click Yes to replace the existing file.

If you select a specific pier(s) or spandrel(s) before using the **File menu > Print Tables > Shear Wall Design** command, the Selection Only check box will be checked. The print will be for the selected specific pier(s) or spandrel(s) only. If you uncheck the Selection Only check box, data will be printed for all piers and spandrels in the design.

Preferences

The program provides preferences output in tabular form with column headings. Table 1 lists each of those column headings and provides a brief explanation of the information provided. See Shear Wall Design UBC 97 Technical Note 11 Preference and Shear Wall Design ACI318-99 Technical Note 22 Preferences for more information.

Table 1 Shear Wall Design Preferences Output

COLUMN HEADING	DESCRIPTION
Flags and Factors	
Time Hist Design	Toggle for designing the load combinations that include a time history using the envelope of the time history or the step-by-step option for the entire time history. See the section entitled "Design Load Combinations that Include Time History Results" in Shear Wall Design UBC 97 Technical Note 13 Design Load Combinations or in Shear Wall Design ACI318-99 Technical Note 24 Design Load Combinations for more information. Additional code-specific input data also is available. See Shear Wall Design UBC 97 Technical Note 11 Preference and Shear Wall Design ACI318-99 Technical Note 22 Preferences for more information.
Rebar Units	
Area Units	Units used for concentrated areas of reinforcing steel. See "Units" in Shear Wall Design Technical Note 1 General Design Information.
Area/Length Units	Units used for distributed areas of reinforcing steel. See "Units" in Shear Wall Design Technical Note 1 General Design Information.

Table 1 Shear Wall Design Preferences Output

COLUMN HEADING	DESCRIPTION
Simplified Pier Reinforcing Ratio Limits	
Edge Memb PT-Max	Maximum ratio of tension reinforcing allowed in edge members of simplified piers, PT_{max}. See "Design Condition 1" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design and Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design for more information.
Edge Memb PC-Max	Maximum ratio of compression reinforcing allowed in edge members of simplified piers, PC_{max}. See "Design Condition 1" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design and Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design for more information.
Interaction Surface Data	
Number Curves	Number of equally spaced interaction curves used to create a full 360 degree interaction surface. See "Interaction Surface" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design and in Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design for more information.
Number Points	Number of points used for defining a single curve in a wall pier interaction surface. See "Interaction Surface" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design and in Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design for more information.
Sect Des IP-Max	The maximum ratio of reinforcing considered in the *design* of a pier with a Section Designer section. See "Designing a General Reinforcing Pier Section" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design and in Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design for more information.
Sect Des IP-Min	The minimum ratio of reinforcing considered in the *design* of a pier with a Section Designer section. See "Designing a General Reinforcing Pier Section" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design and in Shear Wall Design ACI318-99 Technical Note 25 Wall Pier Flexural Design for more information.

Input Summary

The program presents the input summary in tabular form with column headings. Table 2 identifies each of those column headings and provides a brief explanation of the information provided under each heading.

Note:

Use the **File menu > Print Tables > Shear Wall Design** command to print the input summary.

Table 2 Input Data Summary

COLUMN HEADING	DESCRIPTION
Pier Location Data	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Pier Height	The height of the pier measured from the bottom of the pier to the top of the pier.
Axis Angle	The angle in degrees measured from the positive global X-axis to the positive local 2-axis of the pier.
Station Location	This is either Top or Bottom and designates the top or the bottom of the pier.
Xc Ordinate	The global X coordinate of the centroid of the considered station (top or bottom of the pier).
Yc Ordinate	The global Y coordinate of the centroid of the considered station (top or bottom of the pier).
Zc Ordinate	The global Z coordinate of the centroid of the considered station (top or bottom of the pier).
Pier Basic Overwrite Data	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Design Active	Toggle to design the pier. It is either Yes or No. This item corresponds to the "Design this Pier" item in the pier design overwrites.
RLLF	A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load. If the value of this item is calculated by the program, it is reported here as "Prog Calc."

Table 2 Input Data Summary

COLUMN HEADING	DESCRIPTION
EQF	A multiplier applied to horizontal earthquake loads. This item corresponds to the Horizontal EQ Factor item in the pier design overwrites. See "EQ Factor" in Shear Wall Design UBC97 Technical Note 12 Shear Wall Design Overwrites or in Shear Wall Design ACI318-99 Technical Note 23 Shear Wall Design Overwrites for more information.
Design Type	This item is either "Seismic" or "Nonseismic." Additional design checks are performed for seismic elements compared to non-seismic elements. Also, in some cases the strength reduction factors are different.
Pier Type	This item is either "Uniform", "General", or "Simplified." It indicates the type of pier. This item corresponds to the "Pier Section Type" item in the pier design overwrites.
Uniform Reinforcing Sections	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Pier Material	The material property associated with the pier.
Edge Bar	Specified bar size of uniformly spaced edge bars.
Edge Spacing	Specified bar spacing for uniformly spaced edge bars.
End/Corner Bar	Specified bar size of end and corner bars.
Clear Cover	Specified clear cover for the edge, end and corner bars.
Design Or Check	This item is "Design" if the pier is to be designed. It is "Check" if the pier is to be checked.
General Reinforcing Sections	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Bot Pier Section	The name of the General Reinforcing pier section assigned to the bottom of the pier.
Top Pier Section	The name of the General Reinforcing pier section assigned to the top of the pier.
Bot Pier Material	The base material property associated with the section at the bottom of the pier. The base material is described in the Section Designer Manual.

Table 2 Input Data Summary

COLUMN HEADING	DESCRIPTION
Top Pier Material	The base material property associated with the section at the top of the pier. The base material is described in the Section Designer Manual.
Design Or Check	This item is "Design" if the pier is to be designed. It is "Check" if the pier is to be checked.
Simplified T and C Sections	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Pier Material	The material property associated with the pier.
Station Location	This is either Top or Bottom to designate the top or the bottom of the pier.
Pier Thick	The design thickness of the pier. If the value of this item is calculated by the program, it is reported here as "Prog Calc."
Pier Length	The design length of the pier. If the value of this item is calculated by the program, it is reported here as "Prog Calc."
DB1 Left	The user-defined length of the edge member at the left end of the pier. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Sections .
DB2 Left	The user-defined width of the edge member at the left end of the pier. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Sections.
DB1 Right	The user-defined length of the edge member at the right end of the pier. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Sections.
DB2 Right	The user-defined width of the edge member at the right end of the pier. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Sections.
Spandrel Location Data	
Story Label	Label of the story level associated with the spandrel.
Spandrel Label	Label assigned to the spandrel.
Spandrel Length	The length of the spandrel measured from the left end of the spandrel to the right end.
Axis Angle	The angle in degrees measured from the positive global X-axis to the positive local 1-axis of the spandrel.

Table 2 Input Data Summary

COLUMN HEADING	DESCRIPTION
Station Location	This is either Left or Right to designate the left end or the right end of the spandrel.
Xc Ordinate	The global X coordinate of the centroid of the considered station (left or right of the spandrel).
Yc Ordinate	The global Y coordinate of the centroid of the considered station (left or right of the spandrel).
Zc Ordinate	The global Z coordinate of the centroid of the considered station (left or right of the spandrel).
Spandrel Basic Overwrite Data	
Story Label	Label of the story level associated with the spandrel.
Spandrel Label	Label assigned to the spandrel.
Design Active	Toggle to design the spandrel. It is either Yes or No. This item corresponds to the "Design this Spandrel" item in the spandrel design overwrites.
RLLF	A reducible live load acting on a spandrel is multiplied by this factor to obtain the reduced live load. If the value of this item is calculated by the program, it is reported here as "Prog Calc."
Design Type	This item is either "Seismic" or "Nonseismic." Additional design checks are performed for seismic elements compared to non-seismic elements. Also, in some cases, the strength reduction factors are different.
Material Label	The material property associated with the spandrel. If this item is calculated by the program, it is reported here as "Prog Calc."
Consider Vc	A toggle switch for considering V_c (the concrete shear capacity) when computing the shear capacity of the spandrel. This item is either Yes or No.
Spandrel Geometry Data	
Story Label	Label of the story level associated with the spandrel.
Spandrel Label	Label assigned to the spandrel.
Station Location	This is either Left or Right to designate the left end or the right end of the spandrel.
Spandrel Height	Full height (depth) of the spandrel. If the value of this item is calculated by the program, it is reported here as "Prog Calc."

Table 2 Input Data Summary

COLUMN HEADING	DESCRIPTION
Spandrel Thick	Thickness (width) of the spandrel. For T-beams, this is the width of the beam web. If the value of this item is calculated by the program, it is reported here as "Prog Calc."
Flange Width	Full width of the flange for a T-beam. If the spandrel is not a T-beam, this item is zero.
Flange Depth	Depth of the flange for a T-beam. If the spandrel is not a T-beam, this item is zero.
Cover Top	Distance from the top of the beam to the centroid of the top longitudinal reinforcing. If the value of this item is calculated by the program, it is reported here as "Prog Calc."
Cover Bot	Distance from the bottom of the beam to the centroid of the bottom longitudinal reinforcing. If the value of this item is calculated by the program, it is reported here as "Prog Calc."

Technical Note 5
Output Details

Overview

This Technical Note describes the wall pier/spandrel design output summary that can be printed to a printer or to a text file.

Using the Print Design Tables Form

To print the wall pier/spandrel design summary to a printer or to a text file, click the **File menu > Print Tables > Shear Wall Design** command and check the Output Summary check box on the Print Design Tables form. A design must have been run for this check box to be available.

If you click the **OK** button after checking the Output Summary check box, the program will create a PDF file of the output and will prompt you for a path and filename. After it has been saved, the file will display using Adobe Acrobat or Acrobat Reader. Select File Print.

To generate output in a format other than PDF, click the Print to File check box. Click the **Filename** button to change the path or filename. Use the appropriate file extension for the desired format (e.g., .txt, .xls, .doc). Click the **OK** button to complete the print request. Click the **Cancel** button to cancel the print request.

Note:

The **File menu > Display Input/Output Text Files** command is useful for displaying output that is printed to a text file.

The Append check box allows you to add data to an existing file. Use the **Filename** button to locate the existing file. Click the **OK** or **Cancel** button to complete or cancel the print request.

If you select a specific pier(s) or spandrel(s) before using the **File menu > Print Tables > Shear Wall Design** command, the Selection Only check box will be checked.

Output Summary

The program provides the output summary in tabular form with column headings. Table 1 identifies each of those column headings and provides a brief explanation of the information provided.

Table 1 Shear Wall Design Output Summary

COLUMN HEADING	DESCRIPTION
Simplified Pier Section Design	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Sta Loc	This is either Top or Bot to designate the top or the bottom of the pier.
Edge Memb Left	The length of the user-defined edge member, DB1, or the length of the program-determined edge member at the left side of the pier.
Edge Memb Right	The length of the user-defined edge member, DB1, or the length of the program-determined edge member at the right side of the pier.
As Left	The required area of steel at the center of the edge member at the left side of the pier. Note that the area of steel reported here is the maximum of the required tension steel and the required compression steel.
As Right	The required area of steel at the center of the edge member at the right side of the pier. Note that the area of steel reported here is the maximum of the required tension steel and the required compression steel.
Av Shear	The required area per unit length (height) of horizontal shear reinforcing steel in the pier.
B-Zone Length	This item applies only to codes that consider boundary zones. This is a required length, such as 22.762 inches, or it is "Not Needed," or it is "Not Checked." Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is performed by the program.
Uniform Reinforcing Pier Sections - Design	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.

Table 1 Shear Wall Design Output Summary

COLUMN HEADING	DESCRIPTION
Sta Loc	This is either Top or Bot to designate the top or the bottom of the pier.
Edge Bar	The size of the uniformly spaced edge bars.
End Bar	The size of the end and corner bars.
Edge Spacing	The spacing of the uniformly spaced edge bars.
Required Ratio	The maximum required ratio of reinforcing for the pier. This is equal to the total area of vertical steel in the pier divided by area of the pier.
Current Ratio	The ratio of the actual reinforcing specified in the Section Designer section divided by the area of the Section Designer section. This ratio is provided as a benchmark to help you understand how much reinforcing is actually required in the section.
Pier Leg	The pier leg to which the associated shear and boundary zone output applies.
Shear Av	The maximum area per unit length (height) of horizontal reinforcing steel required to resist shear in the specified pier leg
B-Zone Length	This item applies only to codes that consider boundary zones. This is a required length, such as 22.762 inches, or it is "Not Needed," or it is "Not Checked." Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is performed by the program.
General Reinforcing Pier Sections - Design	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Sta Loc	This is either Top or Bot to designate the top or the bottom of the pier.
Pier Section	The name of the Section Designer section assigned to the pier at the considered station location (top or bottom of pier).

Table 1 Shear Wall Design Output Summary

COLUMN HEADING	DESCRIPTION
Required Ratio	The maximum required ratio of reinforcing for the pier. This is equal to the total area of vertical steel in the pier divided by area of the pier. The required reinforcing is assumed to be provided in the same proportions as specified in the Section Designer section. For example, assume the Current Ratio (see next item) is 0.0200 and the Required Ratio is 0.0592. The section should be adequate if you triple the size of each bar that is currently specified in the Section Designer section. We recommend that you always do this final check by modifying the bar size in the Section Designer section, indicating that the section is to be checked (not designed), and rerunning the design.
Current Ratio	The ratio of the actual reinforcing specified in the Section Designer section divided by the area of the Section Designer section. This ratio is provided as a benchmark to help you understand how much reinforcing is actually required in the section.

Note:

The area of the Section Designer section that is used in computing the Required Ratio and the Current Ratio is the actual area of the pier. This may be different from the transformed area that is reported by Section Designer. See the Section Designer Manual for more information.

COLUMN HEADING	DESCRIPTION
Pier Leg	The pier leg to which the associated shear and boundary zone output applies.
Shear Av	The maximum area per unit length (height) of horizontal reinforcing steel required to resist shear in the specified pier leg
B-Zone Length	This item applies only to codes that consider boundary zones. This is a required length, such as 22.762 inches, or it is "Not Needed," or it is "Not Checked." Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is performed by the program.

Table 1 Shear Wall Design Output Summary

COLUMN HEADING	DESCRIPTION
Note: See Shear Wall Design UBC97 Technical Note 18 Wall Pier Boundary Elements or Shear Wall Design ACI318-99 Technical Note 29 Wall Pier Boundary Elements for a description of the boundary zone check.	
Uniform Reinforcing Pier Sections - Check	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Sta Loc	This is either Top or Bot to designate the top or the bottom of the pier.
Edge Bar	The size of the uniformly spaced edge bars.
End Bar	The size of the end and corner bars.
Edge Spacing	The spacing of the uniformly spaced edge bars.
Pier Leg	The pier leg to which the associated shear and boundary zone output applies.
D/C Ratio	The maximum demand/capacity ratio for the pier.
Shear Av	The maximum area per unit length (height) of horizontal reinforcing steel required to resist shear in the specified pier leg
B-Zone Length	This item applies only to codes that consider boundary zones. This is a required length, such as 22.762 inches, or it is "Not Needed," or it is "Not Checked." Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is performed by the program.
General Reinforcing Pier Sections - Check	
Story Label	Label of the story level associated with the pier.
Pier Label	Label assigned to the pier.
Sta Loc	This is either Top or Bot to designate the top or the bottom of the pier.
Pier Section	The name of the Section Designer section assigned to the pier at the considered station location (top or bottom of pier).
D/C Ratio	The maximum demand/capacity ratio for the pier.
Pier Leg	The pier leg to which the associated shear and boundary zone output applies.

Table 1 Shear Wall Design Output Summary

COLUMN HEADING	DESCRIPTION
Shear Av	The maximum area per unit length (height) of horizontal reinforcing steel required to resist shear in the specified pier leg
B-Zone Length	This item applies only to codes that consider boundary zones. This is a required length, such as 22.762 inches, or it is "Not Needed," or it is "Not Checked." Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is performed by the program.
Spandrel Design	
Story Label	Label of the story level associated with the spandrel.
Spandrel Label	Label assigned to the spandrel.
Station Location	This is either Left or Right to designate the left end or the right end of the spandrel.
L/d Ratio	The length of the spandrel divided by the depth.
Shear Vc	The concrete shear capacity used in the spandrel design. See "Determine the Concrete Shear Capacity" in Shear Wall Design UBC 97 Technical Note 17 Spandrel Shear Design or in Shear Wall Design ACI318-99 Technical Note 28 Spandrel Shear Design for more information.
Required Reinforcing Steel	
M{top}	The required area of flexural reinforcing steel at the top of the spandrel.
M{bot}	The required area of flexural reinforcing steel at the bottom of the spandrel.
Av	The required area per unit length of vertical shear reinforcing steel in the spandrel.
Ah	The required area per unit length (height) of horizontal shear reinforcing steel in the spandrel.
Avd	The required area of diagonal shear reinforcing steel in the spandrel. This item is only calculated for seismic piers.

Technical Note 6
Wall Pier Design Sections

There are three types of wall pier design sections available in the program. They are Uniform Reinforcing, General Reinforcing and Simplified T and C pier sections (T and C is short for tension and compression). This Technical Note describes each of these types of pier sections.

By default the program assumes that all piers are Uniform Reinforcing Pier Sections.

Simplified Pier Design Dimensions and Properties

This section describes the design dimensions and the material properties associated with the simplified pier design section. You can define a simplified T and C wall pier design section using the pier design overwrites.

Design Dimensions

A simplified T and C pier section is always planar (not three-dimensional). Figure 1 illustrates some typical dimensions associated with the simplified design of wall piers. The dimensions illustrated are specified in the shear wall overwrites, and they can be specified differently at the top and bottom of the wall pier. The dimensions shown in the figure include the following:

- The length of the wall pier is designated L_p. This is the horizontal length of the wall pier in plan.

- The thickness of the wall pier is designated t_p. The thickness specified for left and right edge members ($DB2_{left}$ and $DB2_{right}$) may be different from this wall thickness.

- DB1 represents the horizontal length of the pier edge member. DB1 can be different at the left and right sides of the pier.

- DB2 represents the horizontal width (or thickness) of the pier edge member. DB2 can be different at the left and right sides of the pier.

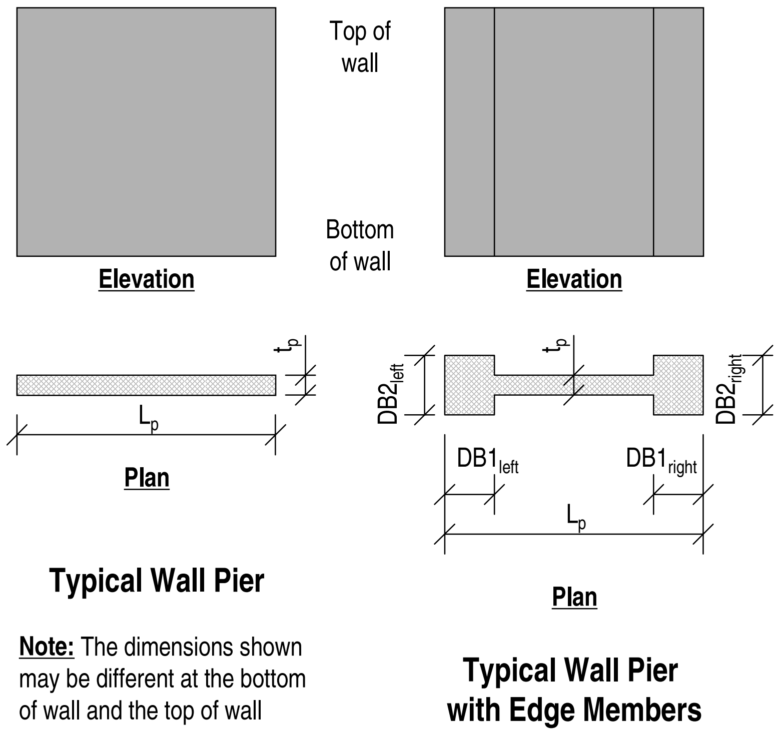


Figure 1: Typical Wall Pier Dimensions Used for Simplified Design

How the Program Calculates the Default Dimensions

This section describes how the program determines the default design dimensions for a simplified pier design section. The default design dimensions consist of a length and a thickness at the top and the bottom of the pier.

Note:

The program automatically picks up the default design dimensions of a pier element from the assignments made to the objects associated with the pier. Use pier design overwrites to revise the default geometry.

The program calculates the default pier lengths at the top and bottom of the pier as the maximum plan dimension of the analysis section at the top and bottom of the pier, respectively. Typically, the line objects (columns) that are part of the pier do not contribute to this length, unless there are no area objects in the pier. In that case, the program picks up the length from the line objects (columns).

The program internally calculates the pier area at the top and bottom of the pier. This pier area includes contributions from both area and line objects.

The default thickness at the top of the pier is calculated as the area at the top of the pier divided by the pier length at the top of the pier. Similarly, the default thickness at the bottom of the pier is calculated as the area at the bottom of the pier divided by the pier length at the bottom of the pier.

By default, the program always assumes that no thickened edge members are included in a simplified pier design section. That is, it assumes that DB1 and DB2 are zero.

Material Properties

The default design material property used for the design of a simplified wall pier is picked up from the first defined area object that is associated with the pier. If no area objects are associated with the pier, the material property is taken from the first defined line object associated with the pier. The user does not know nor can the user determine which object area was defined first. Thus, when a pier is made up of different objects that have different material properties assigned to them, check the pier material property (in the overwrites) to make sure the material property is correct.

General Reinforcing Pier Section

A general reinforcing pier section is defined using the Section Designer utility. Here the user defines the geometry of the pier section and the size and location of the vertical reinforcing steel. The plan section of a general reinforcing section can have any shape. The material properties associated with a general reinforcing pier section are defined as a part of the Section Designer pier, not in the overwrites.

Use the **Design menu > Shear Wall Design > Define General Pier Sections** command to define the sections in Section Designer. After the General Reinforcing Pier Sections have been defined, they can then be assigned to the top and bottom of the pier element, either in the overwrites or using the **Design menu > Shear Wall Design > Assign Pier Section Type > General Reinforcing Pier Section** command.

Important Note: For general reinforcing pier sections only, flexural design is performed based on the section defined in Section Designer. See the subsection entitled "Shear Design Dimensions for Uniform and General Reinforcing Pier Sections" later in this technical note for more information concerning shear design and boundary zone checks.

Uniform Reinforcing Pier Section

The geometry of a uniform reinforcing pier section is picked up automatically by the program from the area objects that define the pier section. If the pier section is made up of line objects only, the line objects are considered by the program when determining the pier geometry. The uniform reinforcing section can be planar or three-dimensional.

The reinforcing size, spacing and clear cover for the uniform reinforcing pier section is defined in the overwrites or using the **Design menu > Shear Wall Design > Assign Pier Section Type > Uniform Reinforcing Pier Section** command. The reinforcing size, spacing and clear cover specified apply at both the top and the bottom of the pier.

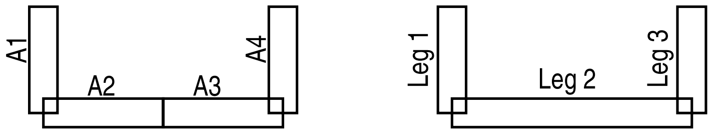
The default design material property used for the uniform reinforcing pier section is the same as that described for Simplified T and C Sections earlier in this technical note.

See the subsection entitled "Shear Design Dimensions for Uniform and General Reinforcing Pier Sections" later in this technical note for more information concerning shear design and boundary zone checks.

Shear Design Dimensions for Uniform and General Reinforcing Pier Sections

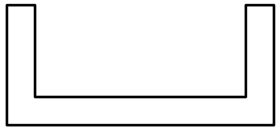
For shear design and boundary element checks, the uniform and general reinforcing pier sections are automatically, and internally to the program, broken up into planar legs. The shear design and boundary zone check are performed for each of the planar legs separately.

The geometry of each planar leg is based on the area objects that define the pier section. If the pier section is made up of line objects only, the line objects define the geometry of the planar legs. It is important to note that for general reinforcing sections, the geometry of the planar legs used for shear design and boundary checks is **not** based on the Section Designer section.



a) Plan View of Area Objects in Object-Based Model

b) Plan View of Idealization for Shear Design and Boundary Zone Checks



c) Plan View of Idealization for Flexural Design or Check

Figure 2: Uniform and General Reinforcing Pier Idealization for Shear Design and for Boundary Element Checks

Instead it is based on the geometry of the objects in your object-based building model.

Consider the example C-shaped wall pier shown in Figure 2. Figure 2a shows the plan layout of the area objects in the object-based building model that define the wall pier. These objects are labeled A1 through A4.

Figure 2b shows the idealization of this wall pier for shear design and boundary zone checks, if applicable. Note that the pier is broken up into three legs labeled Leg 1 through Leg 3. The shear design and boundary zone check are performed separately for each leg based on the forces in the leg. This automatically accounts for torsion in three-dimensional wall piers.

Figure 2c shows the idealization of this wall for flexural design as a single, three-dimensional element. For clarity, the rebar is not shown in the figure. This is the section geometry that would be used for a uniform reinforcing pier section, and it is the initial default section for a general reinforcing pier. Note that for flexural design, the geometry of a general reinforcing pier section can be modified by the user in the Section Designer utility.

The design output for shear design and boundary elements refers to the legs by leg number. The detailed printed output for the shear wall design reports the global coordinates of the point at each end of each leg. It also reports the length and thickness of each leg.

Technical Note 7
Wall Spandrel Design Sections

This Technical Note explains how the program designs wall spandrel sections, including wall spandrel design dimensions, default design dimensions, and the default design material property. In this program, all wall spandrels are two-dimensional. The program determines the wall spandrel design dimensions and material properties automatically. These dimensions and properties can be modified in the spandrel design overwrites.

Note that different dimensions can be specified at the left and right ends of a spandrel.

Wall Spandrel Design Dimensions

Figure 1 illustrates some typical design dimensions associated with wall spandrels. The dimensions illustrated can be specified differently at the left and right sides of the wall spandrel. The dimensions shown in the figure include the following:

- The length of the wall spandrel is designated Ls. This is the horizontal length of the wall spandrel in plan.
- The height of the wall spandrel is designated h_s. This is the vertical distance from the bottom of the spandrel to the top of the spandrel.
- The thickness of the wall spandrel web is designated t_s.
- The effective width of the slab for T-beam action (if specified) is b_s.
- The depth of the slab for T-beam action (if specified) is d_s.

Note:

The wall spandrel design dimensions are specified in the spandrel design overwrites. The design dimensions can, if desired, be different at the left and right ends of the spandrel.

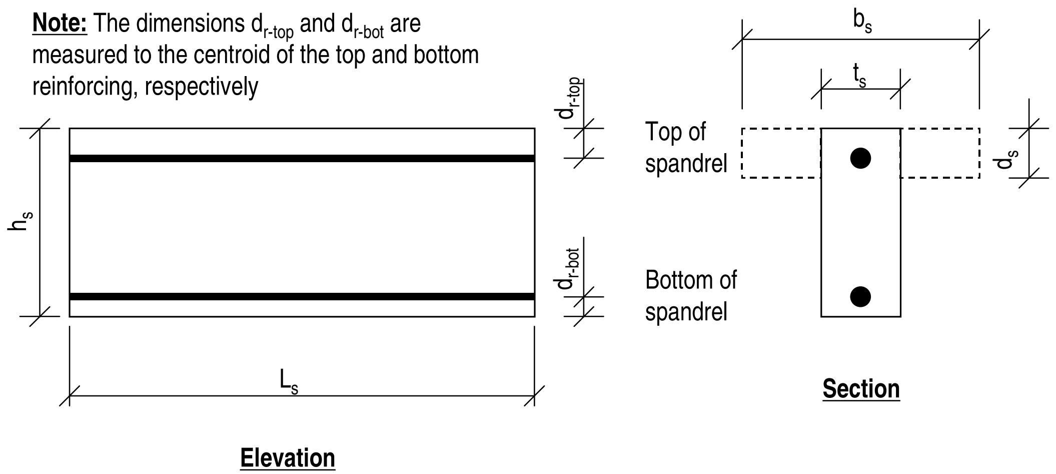


Figure 1: Typical Wall Spandrel Dimensions

- The distance from the bottom of the beam to the centroid of the bottom flexural reinforcing is $d_{r\text{-}bot}$. Note that for the purpose of calculating or checking spandrel beam flexural steel, all of the bottom steel is assumed to occur at this location.

- The distance from the top of the beam to the centroid of the top flexural reinforcing is $d_{r\text{-}top}$. Note that for the purpose of calculating or checking spandrel beam flexural steel, all of the top steel is assumed to occur at this location.

Default Design Dimensions

This section describes how the program determines the default design dimensions for a spandrel. The default design dimensions consist of a length, thickness and depth. The design length of the spandrel is measured in the local 1-axis direction of the spandrel.

Note:

Spandrel beams can be specified as T-beam sections for design, if desired.

The program calculates the default spandrel design depth at the left and right ends of the spandrel as the maximum vertical dimension of the analysis section at the left and right ends of the spandrel, respectively. Typically, the line objects (beams) that are part of the spandrel do not contribute to this depth unless there are no area objects in the spandrel. In that case, the program picks up the depth from the line objects (beams).

The program internally calculates the analysis section spandrel area at the left and right ends of the spandrel. This spandrel area includes contribution from both area and line objects.

Note:

The program automatically picks up the default dimensions of a spandrel element from the assignments made to the objects associated with the spandrel. Use the spandrel design overwrites to revise the default dimensions.

The default design thickness at the left end of the spandrel is calculated as the area at the left end of the spandrel divided by the spandrel depth at the left end of the spandrel. Similarly, the default thickness at the right end of the spandrel is calculated as the area at the right end of the spandrel divided by the spandrel depth at the right end of the spandrel.

There are two ways to check the design thickness:

- Click the **Design menu > Shear Wall Design > Display Design Info** command, click the Design Input check box, and select Thickness in the drop-down box.
- Select an area object that is part of the spandrel and click the **Design menu > Shear Wall Design > View/Revise Spandrel Overwrites** command.

The program assumes that the thickness it picks up from the first area object applies at both the left and right sides of the spandrel. Change the thickness of the left or the right side by revising it in the overwrites.

The default rebar cover to the centroid of the reinforcing is taken as 0.1 times the depth of the section.

The wall spandrel design dimensions can be modified by the user in the spandrel design overwrites. See Shear Wall Design UBC 97 Technical Note 12 Overwrites or Shear Wall Design ACI318-99 Technical Note 23 Overwrites for a description of the overwrites.

Default Design Material Property

The design material property used for the design of a wall spandrel beam is picked up from the first defined area object that is associated with the spandrel. If there are no area objects associated with the spandrel, the material property is taken from the first defined line object associated with the spandrel. The user does not know nor can the user determine which object area was defined first. Thus, when a spandrel is made up of different objects that have different material properties assigned to them, check the spandrel material property carefully (using one of the two methods described in the previous section for checking the spandrel thickness) to make sure the material property is correct. If it is not, revise the material property in the spandrel design overwrites.

SHEAR WALL DESIGN

Technical Note 8
Define Pier Reinforcing Using Section Designer

This Technical Note provides basic instruction for using the Section Designer utility of the program to specify user-defined vertical reinforcing for wall piers. Many options and features are available in Section Designer (see the Section Designer manual). Section Designer is intended to be used for much more than just defining wall piers. This Technical Note does not try to document all of the options and features. Instead, it concentrates on a few of the basic features that will help you define wall piers and their vertical reinforcing.

Tip:

You must fully understand the wall pier orientation information provided in this chapter if you are specifying user-defined flexural reinforcing for a wall pier that is unsymmetrical in plan.

Local Axes Definition and Orientation

Before you begin to draw a wall section in Section Designer, it is crucial that you understand the local axes definition for the pier and that you understand the orientation that the program assumes for the pier.

In Section Designer, a plan view section of the pier is displayed, *always*. The positive local 2-axis is horizontal pointing to the right, *always*. The positive local 3-axis is vertical pointing up, *always* (unless, of course, you turn your computer monitor upside down). The local 1-axis points toward you.

You should carefully consider the local axes orientation before beginning to draw your pier section in Section Designer. This will help you avoid having a pier section with the wrong orientation.

Initial Definition of a Wall Pier Section

Starting Section Designer

Begin to define a wall pier section with user-defined vertical reinforcing by clicking **Design menu > Shear Wall Design > Define Pier Sections for**

Checking. This command brings up the Pier Sections form. Click the **Add Pier Section** button to start a new section or click the **Modify/Show Pier Section** button to view and modify a previously defined pier section.

Tip:

It is usually easier and quicker to start from the analysis pier section geometry rather than starting from scratch.

Clicking the **Add Pier Section** button brings up the Pier Section Data form. The following bullet items describe the various areas in this form:

- **Section Name:** This is the name of the pier section.

- **Base Material:** This is the material property used for the pier section.

- **Add Pier:** The Add New Pier Section option allows you to start the pier section from scratch. See the subsection later in this Technical Note entitled "Creating a Pier Section from Scratch" for more information.

  The Start from Existing Wall Pier option allows you to start with the geometry of an existing wall pier. When selecting this option, also specify a story and a wall pier label so that the program knows which existing pier geometry to use. In cases where the top and bottom geometry of the pier are different, the program uses the geometry at the *bottom* of the pier. See the subsection later in this Technical Note entitled "Creating a Pier from the Geometry of an Existing Analysis Pier Section" for more information.

- **Check/Design:** Select the Reinforcement to be Checked option to specify your own reinforcement (location and size) and have the program check it.

  Select the Reinforcement to be Designed if you want the program to determine the required amount of reinforcing for you. In that case, the reinforcing bars must still be laid out in Section Designer. The program will use that layout and report the required percentage of steel. When the design option is used, always specify your actual final reinforcing at the end of the design process and have the program check it.

- **Define/Edit/Show Section:** After data has been specified in the other areas of the form, click the **Section Designer** button to enter the section designer utility and define the pier geometry and the reinforcing.

  When you have finished using Section Designer, close it and return to the Pier Section data form and click the **OK** button to complete the definition of the pier.

Creating a Pier Section from Scratch

Begin defining a pier section from scratch in Section Designer by drawing the concrete section. Click the **Draw Polygon Section** button located on the side toolbar, or select **Draw menu > Draw Polygon**. Then, left click the mouse on each corner point of the polygon that describes the wall pier section. Proceed around the polygon in either a clockwise or a counter-clockwise direction. Double click on the last point; Section Designer recognizes that you have completed the polygon and draws the shape. Alternatively, press the Enter key on your keyboard after you single click on the last point to finish the polygon.

After the pier section has been drawn, add rebar as described in the subsection entitled "Revising Rebar Size, Cover and Spacing" later in this Technical Note.

Creating a Pier from the Geometry of an Existing Analysis Pier Section

When a pier is created from the geometry of an existing analysis pier section, the geometry of the pier is immediately displayed in Section Designer. Modify the geometry of the section as described in the next subsection, entitled "Modifying the Geometry of the Concrete Section." Add rebar as described in the subsequent subsection, entitled "Revising Rebar Size, Cover and Spacing."

Modifying the Geometry of the Concrete Section

Revise the geometry of a polygon by changing the coordinates of the corner points. First click on the **Reshaper** button located on the side toolbar. Clicking the **Reshaper** button causes handles to appear on each corner of the polygon (assuming you have created the polygon using one of the methods described in the previous section). The two possible methods to change the geometry of the concrete section are as follows:

- Click on one of the handles with the left mouse button, and while still holding the left mouse button down, drag the handle to a new location. Release the left mouse button when you have dragged it to the correct location.
- Click on one of the handles with the right mouse button, and the Change Coordinates form will pop up; type in new coordinates for the corner point of the polygon.

Note:

The information provided here applies only to the corner rebar and rebar line patterns that are part of the polygon area object in Section Designer. It does not apply to individual rebar elements and rebar line patterns that can also be specified in Section Designer but are not discussed in this section because they are not typically needed for wall piers.

Revising Rebar Size, Cover and Spacing

General

By default, for a polygon section, single rebar elements are provided at each corner of the polygon and rebar line patterns are provided along each face of the polygon. Note the following about the rebar elements:

- Rebar line patterns are defined by a rebar size, maximum center-to-center spacing, and clear cover.
- The bars are spaced equally in a rebar line pattern. The equal spacing is measured from the center of the corner bar at one end of the rebar line pattern to the center of the corner bar at the other end of the rebar line pattern.
- Single rebar elements at the corners of a polygon are defined simply by a bar size. The clear cover for these corner bars is determined from the clear cover of the line rebar on either side of the corner bar.

To further illustrate the reinforcing, refer to Figure 1. The figure shows a typical wall pier. The four edges of the pier are arbitrarily labeled Edge A, B, C and D for the purposes of this description. Note the following about the reinforcing steel illustrated in Figure 1:

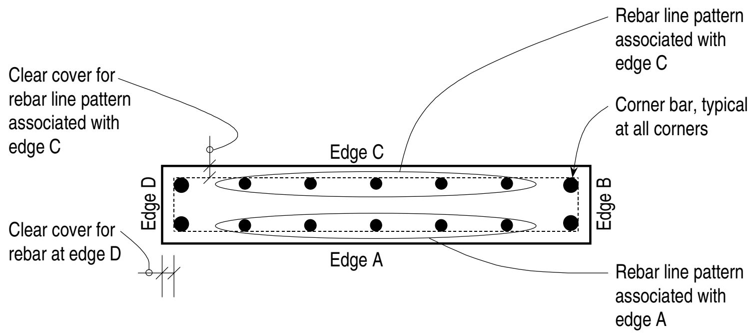


Figure 1: Rebar example

- There are corner bars located at each of the four corners. Consider the corner bar in the upper left-hand corner at the intersection of Edges C and D. This corner bar is located such that the clear distance from Edge D to the bar is equal to the cover distance specified for the rebar line pattern along Edge D. Similarly, the clear distance from Edge C to the corner bar is equal to the cover distance specified for the rebar line pattern along Edge C.
- The corner rebar size may be different at each corner of the pier.
- The rebar line pattern along an edge of the pier is parallel to the edge of the pier and extends from the center of the corner bar (or its projection perpendicular to the pier edge) at one end of the considered edge to the center of the corner bar (or its projection perpendicular to the pier edge) at the other end of the considered edge. The rebar line pattern is then divided into equal spaces whose length does not exceed the specified spacing for the rebar line pattern.
- The rebar line pattern size, spacing and cover may be different along each edge of the pier.

Methodology

To edit rebar line patterns along an edge of the member, simply right click on the rebar line pattern. This activates the Edge Reinforcing form where you can modify the edge rebar size, maximum spacing and clear cover.

Tip:

In Section Designer, right click on a rebar to bring up a pop-up form where you can edit the rebar size, spacing and cover.

A check box in the Edge Reinforcing form, when checked, applies the specified reinforcing to all edges of the polygon. Note that if the rebar size along an edge of the polygon has already been specified to be "None," the Apply to All Edges command does not apply the specified reinforcing size and spacing to that edge. It will, however, apply the specified cover to that edge.

To edit corner rebar, right click on the rebar element. The Corner Point Reinforcing form appears. In this form, specify the size of the corner bar. A check box also allows this size to be applied to all corner bars. Note that if the corner rebar size has already been specified to be "None," the Apply to All Corners command does not apply the specified reinforcing size at that location.

Modifying Material Properties

The material properties used in Section Designer are the same as those defined in the program using the **Define menu > Material Properties** command. To modify a material property, modify the property in the program itself, not in the Section Designer utility.

Note that the material property defines both the concrete strength and the rebar yield stress.

To review or change the material property associated with a pier in Section Designer, right click on the polygon area object that defines the pier to bring up the Section Information form. Material property is one of the items that can be changed in this form.

Interaction Diagrams and Moment-Curvature Plots

You can view an interaction diagram or a moment curvature plot for your pier section at any time in Section Designer.

To view an interaction diagram, click the **Show Interaction Surface** button located on the top toolbar, or click the **Display menu > Show Interaction Surface** command.

To view a moment-curvature plot, click the **Show Moment-Curvature Curve** button located on the top toolbar, or click the **Display menu > Show Moment-Curvature Curve** command.

Technical Note 9
General and Notation

Introduction to the UBC97 Series of Technical Notes

The Shear Wall Design UBC97 series of Technical Notes describes the details of the structural steel design and stress check algorithms used by the program when the user selects the UBC97 design code. The various notations used in this series are described herein.

The design is based on loading combinations specified by the user. To facilitate the design process, the program provides a set of default load combinations that should satisfy requirements for the design of most building type structures. See Shear Wall Design UBC97 Technical Note 13 Design Load Combinations.

The program also performs the following design, check, or analysis procedures in accordance with UBC 1997 requirements:

- Design and check of concrete wall piers for flexural and axial loads; see Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.
- Design of concrete wall piers for shear; see Shear Wall Design UBC97 Technical Note 15 Wall Pier Shear Design.
- Design of concrete shear wall spandrels for flexure; see Shear Wall Design UBC97 Technical Note 16 Spandrel Flexural Design.
- Design of concrete wall spandrels for shear; see Shear Wall Design UBC97 Technical Note 17 Spandrel Shear Design.
- Consideration of the boundary element requirements for concrete wall piers using an approach based on the requirements of Section 1921.6.6.4 in the 1997 UBC; see Shear Wall Design UBC97 Technical Note 18 Wall Pier Boundary Elements.

The program provides detailed output data for Simplified pier section design, Section Designer pier section *design,* Section Designer pier section *check,* and Spandrel design. See Shear Wall Design UBC97 Technical Note 19 Output Details.

English as well as SI and MKS metric units can be used for input. The program code is based on Kip-Inch-Second units. For simplicity, all equations and descriptions presented in this series of Technical Notes corresponds to **pound-inch-second** units unless otherwise noted.

Notation

Following is the notation used in the Shear Wall Design UBC97 series of Technical Notes.

A_{cv} Net area of a wall pier bounded by the length of the wall pier, L_p, and the web thickness, t_p, inches^2.

A_g Gross area of a wall pier, inches^2.

$A_{h\text{-}min}$ Minimum required area of distributed horizontal reinforcing steel required for shear in a wall spandrel, inches^2 / in.

A_s Area of reinforcing steel, inches^2.

A_{sc} Area of reinforcing steel required for compression in a pier edge member, or the required area of tension steel required to balance the compression steel force in a wall spandrel, inches^2.

$A_{sc\text{-}max}$ Maximum area of compression reinforcing steel in a wall pier edge member, inches^2.

A_{sf} The required area of tension reinforcing steel for balancing the concrete compression force in the extruding portion of the concrete flange of a T-beam, inches^2.

A_{st} Area of reinforcing steel required for tension in a pier edge member, inches^2.

$A_{st\text{-}max}$	Maximum area of tension reinforcing steel in a wall pier edge member, inches^2.
A_v	Area of reinforcing steel required for shear, inches^2 / in.
A_{vd}	Area of diagonal shear reinforcement in a coupling beam, inches^2.
$A_{v\text{-}min}$	Minimum required area of distributed vertical reinforcing steel required for shear in a wall spandrel, inches^2 / in.
A_{sw}	The required area of tension reinforcing steel for balancing the concrete compression force in a rectangular concrete beam, or for balancing the concrete compression force in the concrete web of a T-beam, inches^2.
A'_s	Area of compression reinforcing steel in a spandrel, inches^2.
B_1, B_2...	Length of a concrete edge member in a wall with uniform thickness, inches.
C_a	Seismic coefficient provided in UBC Chapter 16, Table 16-Q, unitless.
C_c	Concrete compression force in a wall pier or spandrel, pounds.
C_f	Concrete compression force in the extruding portion of a T-beam flange, pounds.
C_s	Compression force in wall pier or spandrel reinforcing steel, pounds.
C_w	Concrete compression force in the web of a T-beam, pounds.
D/C	Demand/Capacity ratio as measured on an interaction curve for a wall pier, unitless.

DB1	Length of a user-defined wall pier edge member, inches. This can be different on the left and right sides of the pier, and it also can be different at the top and the bottom of the pier. See Figure 1 of Shear Wall Design Technical Note 6 Wall Pier Design Sections.
DB2	Width of a user-defined wall pier edge member, inches. This can be different on the left and right sides of the pier, and it also can be different at the top and the bottom of the pier. See Figure 1 of Shear Wall Design Technical Note 6 Wall Pier Design Sections.
E	The earthquake load on a structure resulting from the combination of the horizontal component, E_h, and the vertical component, E_v.
E_h	The horizontal component of earthquake load.
E_s	Modulus of elasticity of reinforcing steel, psi.
E_v	The vertical component of earthquake load.
I	Importance factor provided in UBC Chapter 16, Table 16-K, unitless.
IP-max	The maximum ratio of reinforcing considered in the design of a pier with a Section Designer section, unitless.
IP-min	The minimum ratio of reinforcing considered in the design of a pier with a Section Designer section, unitless.
L_{BZ}	Horizontal length of the boundary zone at each end of a wall pier, inches.
L_p	Horizontal length of wall pier, inches. This can be different at the top and the bottom of the pier.
L_s	Horizontal length of wall spandrel, inches.
LL	Live load

M_n Nominal bending strength, pound-inches.

M_u Factored bending moment at a design section, pound-inches.

M_{uc} In a wall spandrel with compression reinforcing, the factored bending moment at a design section resisted by the couple between the concrete in compression and the tension steel, pound-inches.

M_{uf} In a wall spandrel with a T-beam section and compression reinforcing, the factored bending moment at a design section resisted by the couple between the concrete in compression in the extruding portion of the flange and the tension steel, pound-inches.

M_{us} In a wall spandrel with compression reinforcing, the factored bending moment at a design section resisted by the couple between the compression steel and the tension steel, pound-inches.

M_{uw} In a wall spandrel with a T-beam section and compression reinforcing, the factored bending moment at a design section resisted by the couple between the concrete in compression in the web and the tension steel, pound-inches.

OC On a wall pier interaction curve the "distance" from the origin to the capacity associated with the point considered.

OL On a wall pier interaction curve the "distance" from the origin to the point considered.

P_b The axial force in a wall pier at a balanced strain condition, pounds.

P_{left} Equivalent axial force in the left edge member of a wall pier used for design, pounds. This may be different at the top and the bottom of the wall pier.

P_{max} Limit on the maximum compressive design strength specified by the 1997 UBC, pounds.

Pmax Factor Factor used to reduce the allowable maximum compressive design strength, unitless. The 1997 UBC specifies this factor to be 0.80. This factor can be revised in the preferences.

P_n Nominal axial strength, pounds.

P_O Nominal axial load strength of a wall pier, pounds.

P_{oc} The maximum compression force a wall pier can carry with strength reduction factors set equal to one, pounds.

P_{ot} The maximum tension force a wall pier can carry with strength reduction factors set equal to one, pounds.

P_{right} Equivalent axial force in the right edge member of a wall pier used for design, pounds. This may be different at the top and the bottom of the wall pier.

P_u Factored axial force at a design section, pounds.

PC_{max} Maximum ratio of compression steel in an edge member of a wall pier, unitless.

PT_{max} Maximum ratio of tension steel in an edge member of a wall pier, unitless.

R_{LW} Shear strength reduction factor as specified in the concrete material properties, unitless. This reduction factor applies to light-weight concrete. It is equal to 1 for normal weight concrete.

RLL Reduced live load.

T_s Tension force in wall pier reinforcing steel, pounds.

V_c The portion of the shear force carried by the concrete, pounds.

V_n Nominal shear strength, pounds.

V_s The portion of the shear force in a spandrel carried by the shear reinforcing steel, pounds.

V_u Factored shear force at a design section, pounds.

WL Wind load.

a Depth of the wall pier or spandrel compression block, inches.

a_b Depth of the compression block in a wall spandrel for balanced strain conditions, inches.

a_1 Depth of the compression block in the web of a T-beam, inches.

b_s Width of the compression flange in a T-beam, inches. This can be different on the left and right end of the T-beam.

c Distance from the extreme compression fiber of the wall pier or spandrel to the neutral axis, inches.

c_b Distance from the extreme compression fiber of a spandrel to the neutral axis for balanced strain conditions, inches.

$d_{r\text{-}bot}$ Distance from bottom of spandrel beam to centroid of the bottom reinforcing steel, inches. This can be different on the left and right ends of the beam.

$d_{r\text{-}top}$ Distance from top of spandrel beam to centroid of the top reinforcing steel, inches. This can be different on the left and right ends of the beam.

d_s Depth of the compression flange in a T-beam, inches. This can be different on the left and right ends of the T-beam.

$d_{spandrel}$ Depth of spandrel beam minus cover to centroid of reinforcing, inches.

f_y Yield strength of steel reinforcing, psi. This value is used for flexural and axial design calculations.

f_{ys} Yield strength of steel reinforcing, psi. This value is used for shear design calculations.

f'_c Concrete compressive strength, psi. This value is used for flexural and axial design calculations.

f'_{cs} Concrete compressive strength, psi. This value is used for shear design calculations.

f'_s Stress in compression steel of a wall spandrel, psi.

h_s Height of a wall spandrel, inches. This can be different on the left and right ends of the spandrel.

p_{max} Maximum ratio of reinforcing steel in a wall pier with a Section Designer section that is designed (not checked), unitless.

p_{min} Minimum ratio of reinforcing steel in a wall pier with a Section Designer section that is designed (not checked), unitless.

t_p Thickness of a wall pier, inches. This can be different at the top and bottom of the pier.

t_s Thickness of a wall spandrel, inches. This can be different on the left and right ends of the spandrel.

ΣDL The sum of all dead load cases.

ΣLL The sum of all live load cases.

ΣRLL The sum of all reduced live load cases.

α The angle between the diagonal reinforcing and the longitudinal axis of a coupling beam.

β_1 Unitless factor defined in Section 1910.2.7.3 of the 1997 UBC.

ε Reinforcing steel strain, unitless.

ε_s Reinforcing steel strain in a wall pier, unitless.

ε'_s Compression steel strain in a wall spandrel, unitless.

ϕ Strength reduction factor, unitless.

ϕ_b Strength reduction factor for bending, unitless. The default value is 0.9.

ϕ_c Strength reduction factor for bending plus high axial compression in a concrete pier, unitless. The default value is 0.7.

ϕ_{vns} Strength reduction factor for shear in a nonseismic pier or spandrel, unitless. The default value is 0.85.

ϕ_{vs} Strength reduction factor for shear in a seismic pier or spandrel, unitless. The default value is 0.6.

ρ Reliability/redundancy factor specified in Section 1630.1.1 of the 1997 UBC, unitless.

σ_s Reinforcing steel stress in a wall pier, psi.

Technical Note 10
Interactive Design Output

Overview

This Technical Note describes how to use interactive shear wall design and review and provides a description of the output obtained when the UBC97 code is selected. Interactive design is a powerful mode that allows quick, on-screen review of design results for a specific pier or spandrel. This mode allows easy modification to design parameters (overwrites) and immediate review of the new results.

Note that a design must have been run for the interactive design mode to be available. To run a design, click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.

To enter the interactive design and review mode, right click on a wall pier or spandrel *while the design results are displayed*. If design results are not currently displayed (and the design has been run), click the **Design menu > Shear Wall Design > Interactive Wall Design** command and then right click a pier or spandrel to enter the interactive design and review mode for that pier or spandrel.

Note that if both a pier and a spandrel label are assigned to the right-clicked object, a pop-up box offers the choice to enter the interactive design and review mode for the pier or for the spandrel.

It may be helpful to read this Technical Note and the following notes to fully understand the output described:

Shear Wall Design Technical Note 1 General Design Information

Shear Wall Design Technical Note 6 Wall Pier Design Sections

Shear Wall Design UBC97 Technical Note 7 Wall Spandrel Design Sections

Shear Wall Design UBC97 Technical Note 11 Preferences

Shear Wall Design UBC97 Technical Note 12 Overwrites

Shear Wall Design UBC97 Technical Note 13 Design Load Combinations

Shear Wall Design UBC97 Technical Note 18 Wall Pier Boundary Elements

Interactive Pier Design and Review

When you right click on a pier for interactive design, the Pier Design form will display. This form provides general information at the top of the box that identifies and locates the pier. Additionally, the form displays output information for flexural design, shear design and the boundary element check.

The look of the interactive pier design and review form is different depending on which of the five types of design you do. The five choices are:

- Design of a pier specified as a Simplified section
- Design of a pier specified as a Uniform Reinforcing section
- Design of a pier specified as a General Reinforcing section
- Check of a pier specified as a Uniform Reinforcing section
- Check of a pier specified as a General Reinforcing section

The output associated with each of these five choices is described in the next three sections.

Design of a Simplified Section

Right clicking on a simplified pier section for interactive design displays the Pier Design form. General information that identifies and locates the pier is displayed at the top of this form. Output information for flexural design, shear design and the boundary element check is also displayed. Several command buttons are on the form. A description of the command buttons is provided at the end of this Technical Note. Table 1 identifies the Data Name and provides a brief Data Description.

Table 1 Output Data for Design of a Simplified Section

DATA NAME	DATA DESCRIPTION
General Identification Data	
Story ID	The story level associated with the pier.
Pier ID	The label assigned to the pier.
X Loc	The global X-coordinate of the plan location of the centroid of the *bottom* of the pier.
Y Loc	The global Y-coordinate of the plan location of the centroid of the *bottom* of the pier.
Flexural Design Data The flexural design data is reported separately for tension design and for compression design. Check the steel area required for both tension and compression design and use the maximum for your pier.	
RLLF	A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.
Tension Design	
Station Location	This is Left Top, Right Top, Left Bottom or Right Bottom and designates the location of the reported reinforcing steel.
Edge Length	Length of the program-determined edge member or length of the user-specified edge member (i.e., DB1). Note that the design algorithm is set up such that the edge length used is always the same for tension design and for compression design.
Tension Rebar	Maximum area of reinforcing steel required to resist tension. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Tension Combo	The design load combination associated with the required tension rebar.
Pu	The factored design axial load associated with the Tension Combo.
Mu	The factored design moment associated with the Tension Combo.

Table 1 Output Data for Design of a Simplified Section

DATA NAME	DATA DESCRIPTION
Compression Design	
Station Location	This is Left Top, Right Top, Left Bottom or Right Bottom and designates the location of the reported reinforcing steel.
Edge Length	Length of the program-determined edge member or length of the user-specified edge member (i.e., DB1). Note that the design algorithm is set up such that the edge length used is always the same for tension design and for compression design.
Compression Rebar	Maximum area of reinforcing steel required to resist compression. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Compression Combo	The design load combination associated with the required compression rebar.
Pu	The factored design axial load associated with the Compression Combo.
Mu	The factored design moment associated with the Compression Combo.
Shear Design Data	
EQF	A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See EQ Factor in Shear Wall Design UBC 97 Technical Note 12 Overwrites for more information.
Station Location	This is either Top or Bot and designates the location (top or bottom) of the reported shear reinforcing steel.
Rebar	Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Shear Combo	The design load combination associated with the specified shear reinforcing.

Table 1 Output Data for Design of a Simplified Section

DATA NAME	DATA DESCRIPTION
Pu	The factored design axial load associated with the Shear Combo.
Mu	The factored design moment associated with the Shear Combo.
Vu	The factored design shear associated with the Shear Combo.
Capacity phi Vc	The shear capacity of the concrete.
Capacity phi Vn	The shear capacity of the section with the specified reinforcing.
Boundary Element Check Data	
Station Location	This is either Top 2-dir or Bot 2-dir and designates the location (top or bottom) of the boundary element check and the direction of force (pier local 2-axis) for which the boundary elements are checked.
B-Zone Length	This is a required length, such as 22.762 inches, or it is *Not Needed*, or it is *Not Checked*. Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is performed by the program because the ratio P_u/P_o is greater than or equal to 0.35. When this item is Not Needed or Not Checked, the program fills in the B-Zone Combo, Pu, Mu, Vu, and Pu/Po items with the data from the design load combination that has the largest P_u/P_o value. Otherwise, the program fills in the data from the design load combination that requires the longest boundary zone length.
B-Zone Combo	The design load combination associated with the specified B-Zone Length.
Pu	The factored design axial load associated with the B-Zone Combo.
Mu	The factored design moment associated with the B-Zone Combo.
Vu	The factored design shear associated with the B-Zone Combo.
Pu/Po	The ratio P_u/P_o associated with the B-Zone Combo. Note that if the ratio is greater than or equal to 0.35, the program does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Design of a Uniform Reinforcing or General Reinforcing Section

Display the Pier Design form by right clicking for interactive design of a pier section that is assigned a Uniform or General Reinforcing section and has been designed by the program. General information identifying and locating the pier is displayed at the top of this form. Output information for flexural design, shear design and the boundary element check is also displayed. Several command buttons are on the form. A description of the command buttons is provided at the end of this Technical Note. Table 2 identifies the Data Name and provides a brief Data Description.

Table 2 Output Data for Design of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
General Identification Data	
Story ID	The story level associated with the pier.
Pier ID	The label assigned to the pier.
X Loc	The global X-coordinate of the plan location of the centroid of the *bottom* of the pier.
Y Loc	The global Y-coordinate of the plan location of the centroid of the *bottom* of the pier.
Flexural Design Data	
RLLF	A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.
Station Location	This is either Top or Bottom and designates that the output on the line is for the top or bottom of the pier.
Required Reinf Ratio	The maximum required ratio of reinforcing for the pier, as determined by the program, such that the demand/capacity ratio is 1.0 (approximately). The ratio is equal to the total area of vertical steel in the pier divided by area of the pier. The required reinforcing is assumed to be provided in the same proportions as specified in the Section Designer section.

Table 2 Output Data for Design of a Uniform or General Section

<table>
<tr><th>DATA NAME</th><th>DATA DESCRIPTION</th></tr>
<tr><td></td><td>For example, assume that the Current Reinf Ratio (see next item) is 0.0200 and the Required Reinf Ratio is 0.0592. In that case, the section should be adequate if you triple the size of each bar that is currently specified in the Section Designer section. Alternatively, you could add more bars.
Important note: We do not recommend that you use the required reinforcing ratio as the final design result. Instead, we recommend that you use it as a guide in defining a General Reinforcing section, with actual reinforcing that is checked by the program (not designed).</td></tr>
<tr><td colspan="2">Tip:
Do not confuse the Required Reinforcing Ratio and the Current Reinforcing Ratio. The important item is the Required Reinforcing Ratio.</td></tr>
<tr><td>Current Reinf Ratio</td><td>The ratio of the actual reinforcing specified in the pier section divided by the area of the pier section. This ratio is provided as a benchmark to help you understand how much reinforcing is actually required in the section.</td></tr>
<tr><td colspan="2">Note:
The area of the pier section that is used in computing the Required Reinf Ratio and the Current Reinf Ratio is the actual area of the pier. This may be different from the transformed area that is reported by Section Designer. See the Section Designer Manual for more information.</td></tr>
<tr><td>Flexural Combo</td><td>The design load combination associated with the specified required reinforcing ratio.</td></tr>
<tr><td>Pu</td><td>The factored design axial load associated with the Flexural Combo.</td></tr>
<tr><td>M2u</td><td>The factored design moment about the pier local 2-axis associated with the Flexural Combo.</td></tr>
<tr><td>M3u</td><td>The factored design moment about the pier local 3-axis associated with the Flexural Combo.</td></tr>
<tr><td colspan="2">Note:
The flexural design of a Uniform or General pier section is always a PMM design that considers both M2 and M3 bending.</td></tr>
</table>

Table 2 Output Data for Design of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
Pier Ag	Gross area of the pier used for flexural calculations.
Shear Design Data	
EQF	A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See EQ Factor in Shear Wall Design UBC 97 Technical Note 12 Overwrites for more information.
Station Location	This is the Top Leg x and the Bot Leg y where x and y represent the worst-case top and bottom pier legs for shear.
Rebar	Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Shear Combo	The design load combination associated with the specified shear reinforcing.
Pu	The factored design axial load associated with the Shear Combo.
Mu	The factored design moment associated with the Shear Combo.
Vu	The factored design shear associated with the Shear Combo.
Boundary Element Check Data	
Station Location	This is Top Leg x and Bot Leg y where x and y represent the worst-case top and bottom pier legs for boundary zones.
B-Zone Length	This is a required length, such as 22.762 inches, or it is *Not Needed*, or it is *Not Checked*. Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is completed by the program because the ratio P_u/P_o is greater than or equal to 0.35. When this item is Not Needed or Not Checked, the program fills in the B-Zone Combo, Pu, Mu, Vu, and Pu/Po items with the data from the design load combination that has the largest P_u/P_o value. Otherwise, the program fills in the data from the design load combination that requires the longest boundary zone length.

Table 2 Output Data for Design of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
B-Zone Combo	The design load combination associated with the specified B-Zone Length.
Pu	The factored design axial load associated with the B-Zone Combo.
Mu	The factored design moment associated with the B-Zone Combo.
Vu	The factored design shear associated with the B-Zone Combo.
Pu/Po	The ratio P_u/P_o associated with the B-Zone Combo. Note that if the ratio is greater than or equal to 0.35, the program does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Check of a Uniform Reinforcing or General Reinforcing Section

Display the Pier Design form by right clicking for interactive design of a pier section that is assigned a Uniform or General Reinforcing section and is designated to be checked (not designed) by the program. General information identifying and locating the pier is displayed at the top of this form. Output information for the flexural check, shear design and the boundary element check is also displayed. Several command buttons are on the form. A description of the command buttons is provided at the end of this Technical Note. Table 3 identifies the Data Name and provides a brief Data Description.

Table 3 Output Data for Check of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
General Identification Data	
Story ID	The story level associated with the pier.
Pier ID	The label assigned to the pier.
X Loc	The global X-coordinate of the plan location of the centroid of the *bottom* of the pier.
Y Loc	The global Y-coordinate of the plan location of the centroid of the *bottom* of the pier.
Flexural Design Data	
RLLF	A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.
Flexural Combo	The design load combination that yields the largest flexural Demand/Capacity ratio.
Station Location	This is either Top or Bottom designating that the output on the line is for the top or bottom of the pier.
D/C Ratio	The Demand/Capacity ratio associated with the Flexural Combo.
Pu	The factored design axial load associated with the Flexural Combo.
M2u	The factored design moment about the pier local 2-axis associated with the Flexural Combo.
M3u	The factored design moment about the pier local 3-axis associated with the Flexural Combo.
Note: The flexural design of a Uniform or General pier section is always a PMM design that considers both M2 and M3 bending.	
Shear Design Data	
EQF	A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See EQ Factor in Shear Wall Design UBC 97 Technical Note 12 Overwrites for more information.
Station Location	This is the Top Leg x and the Bot Leg y where x and y represent the worst-case top and bottom pier legs for shear.

Table 3 Output Data for Check of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
Rebar	Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Shear Combo	The design load combination associated with the specified shear reinforcing.
Pu	The factored design axial load associated with the Shear Combo.
Mu	The factored design moment associated with the Shear Combo.
Vu	The factored design shear associated with the Shear Combo.
Boundary Element Check Data	
Station Location	This is Top Leg x and Bot Leg y where x and y represent the worst-case top and bottom pier legs for boundary zones.
B-Zone Length	This is a required length, such as 22.762 inches, or it is *Not Needed*, or it is *Not Checked*. Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is completed by the program because the ratio P_u/P_o is greater than or equal to 0.35. When this item is Not Needed or Not Checked, the program fills in the B-Zone Combo, Pu, Mu, Vu, and Pu/Po items with the data from the design load combination that has the largest P_u/P_o value. Otherwise, the program fills in the data from the design load combination that requires the longest boundary zone length.
B-Zone Combo	The design load combination associated with the specified B-Zone Length.
Pu	The factored design axial load associated with the B-Zone Combo.
Mu	The factored design moment associated with the B-Zone Combo.
Vu	The factored design shear associated with the B-Zone Combo.

Table 3 Output Data for Check of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
Pu/Po	The ratio P_u/P_o associated with the B-Zone Combo. Note that if the ratio is greater than or equal to 0.35, the program does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Interactive Spandrel Design and Review

Right clicking on a spandrel for interactive design displays the Spandrel Design form. Note that a design must have been run for the interactive design mode to be available. To run a design, click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.

General information identifying and locating the spandrel is displayed at the top of this form. Output information for both flexural and shear design is also displayed, and several command buttons are on the form. A description of the command buttons is provided at the end of this Technical Note. Table 4 identifies the Data Name and provides a brief Data Description.

Table 4 Output Data for Interactive Spandrel Design and Review

DATA NAME	DATA DESCRIPTION
General Identification Data	
Story ID	The story level associated with the spandrel.
Spandrel ID	The label assigned to the spandrel.
X Loc	The global X-coordinate of the plan location of the centroid of the *left* end of the spandrel.
Y Loc	The global Y-coordinate of the plan location of the centroid of the *left* end of the spandrel.
Flexural Design Data	
RLLF	A reducible live load acting on a spandrel is multiplied by this factor to obtain the reduced live load.
Top Steel	
Station Location	This is either Left or Right and designates that the output reported is for the left or right end of the spandrel.

Table 4 Output Data for Interactive Spandrel Design and Review

DATA NAME	DATA DESCRIPTION
Top Steel Area	The area of top steel required for the Top Steel Combo. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Top Steel Ratio	The area of top steel divided by the spandrel thickness divided by the distance from the bottom of the spandrel to the centroid of the top steel, as shown in Equation 1. $$\text{Top Steel Ratio} = \frac{A_{s\ top}}{t_s(h_s - d_{r-top})} \qquad \text{Eqn. 1}$$
Top Steel Combo	The name of the design load combination that requires the most top steel in the spandrel.
Mu	The factored design moment associated with the Top Steel Combo.
Bottom Steel	
Station Location	This is either Left or Right and designates that the output reported is for the left or right end of the spandrel. Note that the bottom steel is only reported at the ends of the spandrel, not at the center of the spandrel.
Bot Steel Area	The area of bottom steel required for the Bot Steel Combo. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Bot Steel Ratio	The area of bottom steel divided by the spandrel thickness divided by the distance from the top of the spandrel to the centroid of the bottom steel, as shown in Equation 2. $$\text{Bot Steel Ratio} = \frac{A_{s\ top}}{t_s(h_s - d_{r-bot})} \qquad \text{Eqn. 2}$$
Bot Steel Combo	The name of the design load combination that requires the most bottom steel in the spandrel.

Table 4 Output Data for Interactive Spandrel Design and Review

DATA NAME	DATA DESCRIPTION
Mu	The factored design moment associated with the Bot Steel Combo.
Shear Design Data	
EQF	A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the spandrel design overwrites. See EQ Factor in Shear Wall Design UBC 97 Technical Note 12 Overwrites for more information.
Design Data for all Spandrels	
Station Location	This is either Left or Right and designates that the output reported is for the left or right end of the spandrel.
Avert	The area per unit length of vertical shear steel required for the Shear Combo. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Ahoriz	The area per unit length (height) of horizontal shear steel required in the spandrel. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Shear Combo	The name of the design load combination that requires the most vertical shear reinforcing steel in the spandrel.
Vu	The factored design shear force at the specified station location associated with the design load combination specified in the Shear Combo column.
Vc	The concrete shear capacity at the specified station location.

Table 4 Output Data for Interactive Spandrel Design and Review

DATA NAME	DATA DESCRIPTION
Note: This additional shear output data is only provided if the "Design is Seismic" item in the spandrel overwrites is set to Yes for the spandrel considered.	
Additional Design Data for Seismic Spandrels Only These items are only displayed if the "Design is Seismic" item in the spandrel overwrites is set to Yes for the spandrel considered.	
Station Location	This is either Left or Right and designates that the output reported is for the left or right end of the spandrel.
Adiag	The area of diagonal shear steel required for the Shear Combo. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Shear Combo	The name of the design load combination that requires the most vertical shear reinforcing steel in the spandrel.
Vu	The factored design shear force at the specified station location associated with the design load combination specified in the Shear Combo column.
Diag Reinf Required	This item is Yes if $V_u > 4\sqrt{f_c'}\ bd_{spandrel}$. Otherwise, it is no.

Command Buttons

Combos Button

Clicking the **Combos** button accesses and allows *temporary* revisions to the design load combinations considered for the pier or spandrel. This may be useful, for example, if you want to see the results for one particular load combination. You can temporarily change the considered design load combinations to be only the one you are interested in and review the results.

The changes made here to the considered design load combinations are temporary. They are not saved when you exit the Pier Design or Spandrel Design form, whether you click **OK** or **Cancel** to exit it.

Overwrites Button

Clicking the **Overwrites** button accesses and allows revisions to the pier or spandrel overwrites and enables immediate review of the revised design results. If you modify some overwrites in this mode and you exit both the Pier Design Overwrites or Spandrel Design overwrites form and the Pier Design or Spandrel Design form by clicking their respective **OK** buttons, the changes made to the overwrites are permanently saved.

Exiting the Pier Design or Spandrel Design Overwrites form by clicking the **OK** button temporarily saves changes. Subsequently exiting the Pier Design or Spandrel Design form by clicking the **Cancel** button *does not* save the changes made to the pier or spandrel overwrites.

To permanently save changes to the overwrites, click the **OK** button to exit the Pier Design or Spandrel Design Overwrites, and then click the **OK** button to exit the Pier Design or Spandrel Design form.

Section Top and Section Bot Buttons

These buttons are only visible if you are designing or checking a pier with a Uniform Reinforcing or General Reinforcing section assigned to it. Clicking these buttons opens Section Designer in a locked (read-only) mode, where you can view the pier.

While in Section Designer, you can review the geometry of the section and the size and location of the rebar. However, you cannot make any changes to the section. You can also review the section properties, interaction surface and moment curvature curve.

Important note: The interaction surface and the moment curvature curve are displayed for the section as it is defined in Section Designer. Thus, when you are designing a pier that is assigned a Section Designer section, the interaction surface and moment curvature curve displayed are for the reinforcing (ratio) drawn in Section Designer, *not the required reinforcing ratio reported in the design output.*

When you have finished reviewing the section in Section Designer, close Section Designer to return to the Pier Design form in the main program.

SHEAR WALL DESIGN UBC97

Technical Note 11
Preferences

General

The shear wall design preferences are basic properties that apply to all wall pier and/or spandrel elements. This Technical Note describes shear wall design preferences for UBC97. To access the shear wall Preferences form, click the **Options menu > Preferences > Shear Wall Design** command.

Default values are provided for all shear wall design preference items. Thus, it is not required that you specify or change any of the preferences. You should, however, at least review the default values for the preference items to make sure they are acceptable to you.

The preference options are described in Table 1, which uses the following column headings:

- **Item:** The name of the preference item as it appears in the cells at the left side of the Preferences form.
- **Possible Values:** The possible values that the associated preference item can have.
- **Default Value:** The built-in default value that the program assumes for the associated preference item.
- **Description:** A description of the associated preference item.

The Flags and Factors used by the program are listed following Table 1. In addition, an explanation of how to change a preference is provided at the end of this Technical Note.

Table 1 Shear Wall Preferences

Item	Possible Values	Default Value	Description
Design Code	Any code in the program	UCB97	Design code used for design of concrete shear wall elements (wall piers and spandrels)
Time History Design	Envelopes or Step-by-Step	Envelopes	Toggle for design load combinations that include a time history designed for the envelope of the time history, or designed step-by-step for the entire time history. If a single design load combination has *more than one* time history case in it, that design load combination is designed for the envelopes of the time histories, regardless of what is specified here.
Rebar units	in^2, cm^2, mm^2, current	in^2 or mm^2	Units used for concentrated areas of reinforcing steel. See "Units" in Shear Wall Design Technical Note 1 General Design Information.
Rebar/Length Units	in^2/ft, cm^2/m, mm^2/m, current	in^2/ft or mm^2/m	Units used for distributed areas of reinforcing steel. See "Units" in Shear Wall Design Technical Note 1 General Design Information.
Number of Curves	≥ 4	24	Number of equally spaced interaction curves used to create a full 360-degree interaction surface (this item should be a multiple of four). We recommend that you use 24 for this item. See "Interaction Surface" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.
Number of Points	≥ 11	11	Number of points used for defining a single curve in a wall pier interaction surface (this item should be odd). See "Interaction Surface" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.
Edge Design PT-max	> 0	0.06	Maximum ratio of tension reinforcing allowed in edge members, PT_{max}. See "Design Condition 1" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.

Table 1 Shear Wall Preferences

Item	Possible Values	Default Value	Description
Edge Design PC-max	> 0	0.04	Maximum ratio of compression reinforcing allowed in edge members, PC_{max}. See "Design Condition 1" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.
Section Design IP-Max	≥ Section Design IP-Min	0.02	The maximum ratio of reinforcing considered in the design of a pier with a Section Designer section. See the section titled "Designing a Section Designer Pier Section" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.
Section Design IP-Min	> 0	0.0025	The minimum ratio of reinforcing considered in the design of a pier with a Section Designer section. See the section titled "Designing a Section Designer Pier Section" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.

Flags and Factors

- **Phi-B Factor:** The strength reduction factor for bending in a wall pier or spandrel, ϕ_b.
- **Phi-C Factor:** The strength reduction factor for axial compression in a wall pier, ϕ_c.
- **Phi-Vns Factor:** The strength reduction factor for shear in a wall pier or spandrel for a nonseismic condition, ϕ_{vns}.
- **Phi-Vs Factor:** The strength reduction factor for shear in a wall pier or spandrel for a seismic condition, ϕ_{vs}.
- **PMax Factor:** A factor used to reduce the allowable maximum compressive design strength. See "Formulation of the Interaction Surface" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design for more information.

Using the Preferences Form

To view preferences, select the **Options menu > Preferences > Shear Wall Design.** The Preferences form will display. The preference options are displayed in a two-column spreadsheet. The left column of the spreadsheet displays the preference item name. The right column of the spreadsheet displays the preference item value.

To change a preference item, left click the desired preference item in either the left or right column of the spreadsheet. This activates a drop-down box or highlights the current preference value. If the drop-down box appears, select a new value. If the cell is highlighted, type in the desired value. The preference value will update accordingly. You cannot overwrite values in the drop-down boxes.

When you have finished making changes to the composite beam preferences, click the **OK** button to close the form. You must click the **OK** button for the changes to be accepted by the program. If you click the **Cancel** button to exit the form, any changes made to the preferences are ignored and the form is closed.

ETABS®

SHEAR WALL DESIGN UBC97

Technical Note 12
Overwrites

General

The shear wall design overwrites are basic assignments that apply only to those piers or spandrels to which they are assigned. The overwrites for piers and spandrels are separate. This Technical Note describes shear wall overwrites for UBC97. Note that the available overwrites change depending on the pier section type (Uniform Reinforcing, General Reinforcing, or Simplified T and C). To access the pier overwrites, select a pier and then click the **Design menu > Shear Wall Design > View/Revise Pier Overwrites** command. To access the spandrel overwrites, select a spandrel and then click the **Design menu > Shear Wall Design > View/Revise Spandrel Overwrites** command.

Default values are provided for all pier and spandrel overwrite items. Thus, you do not need to specify or change any of the overwrites. However, at least review the default values for the overwrite items to make sure they are acceptable. When changes are made to overwrite items, the program applies the changes only to the elements to which they are specifically assigned; that is, to the elements that are selected when the overwrites are changed.

The overwrites are presented in Tables 1 and 2. There are four columns in each table. Each of these columns is described below.

- **Item:** The name of the overwrite item as it appears in the program. To save space in the formes, these names are generally short.
- **Possible Values:** The possible values that the associated overwrite item can have.
- **Default Value:** The default value that the program assumes for the associated overwrite item.
- **Description:** A description of the associated overwrite item.

An explanation of how to change an overwrite is provided at the end of this Technical Note.

Pier Design Overwrites

Table 1 Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Design this Pier	Yes or No	Yes	Toggle for design of the pier when you click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.
LL Reduction Factor	Program calculated, > 0	Program calculated	A reducible live load is multiplied by this factor to obtain the reduced live load. Entering 0 for this item means that it is program calculated. See the subsection entitled "LL Reduction Factor" for more information.
EQ Factor	≥ 0	1	Multiplier on earthquake loads. If 0 is entered for this item, the program re-sets it to the default value of 1 when the next design is run. See the subsection below entitled "EQ Factor" for more information.
Design is Seismic	Yes or No	Yes	Toggle for design as seismic or non-seismic. Additional design checks are performed for seismic elements com-pared to nonseismic elements. Also, in some cases, the strength reduction factors are different.

Table 1 Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Pier Section Type	Uniform Reinforcing, General Reinforcing, Simplified T and C	Uniform Reinforcing	This item indicates the type of pier. The General Reinforcing option is not available unless General pier sections have previously been defined in Section Designer. See "Analysis Sections and Design Sections" in Shear Wall Design Technical Note 1 General Design Information and see Shear Wall Design Technical Note 6 Wall Pier Design Section for more information.
Overwrites Applicable to Uniform Reinforcing Pier Sections			
Edge Bar Name	Any defined bar size	Varies	The size of the uniformly spaced edge bars.
Edge Bar Spacing	>0	12"	The spacing of the uniformly spaced edge bars.
End/Corner Bar Name	Any defined bar size	Varies	The size of end and corner bars.
Clear Cover	>0	1.5"	The clear cover for the edge, end and corner bars.
Material	Any defined concrete material property	Varies	The material property associated with the pier.
Check/Design Reinforcing	Check or Design	Design	This item indicate whether the pier section is to be designed or checked.
Overwrites Applicable to General Reinforcing Pier Sections			
Section Bottom	Any general pier section defined in Section Designer	The first pier in the list of Section Designer piers	Name of a pier section, defined in Section Designer that is assigned to the bottom of the pier.

Table 1 Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Section Top	Any general pier section defined in Section Designer	The first pier in the list of Section Designer piers	Name of a pier section, defined in Section Designer, that is assigned to the top of the pier.
Check/Design Reinforcing	Check or Design	Design	This item indicates whether the pier section is to be designed or checked.
Overwrites Applicable to Simplified T and C Pier Sections			
ThickBot	Program calculated, or > 0	Program calculated	Wall pier thickness at bottom of pier, t_p. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See "How the Program Calculates the Default Dimensions" in Shear Wall Design Technical Note 6 Wall Pier Design Section for more information. Inputting 0 means the item is to be program calculated.
LengthBot	Program calculated, or > 0	Program calculated	Wall pier length at bottom of pier, L_p. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See "How the Program Calculates the Default Dimensions" in Shear Wall Design Technical Note 6 Wall Pier Design Section for more information. Inputting 0 means the item is to be program calculated.
DB1LeftBot	≥ 0	0	Length of the bottom of a user-defined edge member on the left side of a wall pier, $DB1_{left}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See the subsection below entitled "User-Defined Edge Members" for more information.

Table 1 Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
DB1RightBot	≥ 0	Same as DB1-left-bot	Length of the bottom of a user-defined edge member on the right side of a wall pier, $DB1_{right}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See the subsection entitled "User-Defined Edge Members" for more information.
DB2LeftBot	≥ 0	0	Width of the bottom of a user-defined edge member on the left side of a wall pier, $DB2_{left}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See the subsection entitled "User-Defined Edge Members" for more information.
DB2RightBot	≥ 0	Same as DB2-left-bot	Width of the bottom of a user-defined edge member on the right side of a wall pier, $DB2_{right}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See the subsection entitled "User-Defined Edge Members" for more information.
ThickTop	Program calculated, or > 0	Program calculated	Wall pier thickness at top of pier, t_p. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See "How the Program Calculates the Default Dimensions" in Shear Wall Design Technical Note 6 Wall Pier Design Section for more information. Inputting 0 means the item is to be program calculated.

Table 1 Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
LengthTop	Program calculated, or > 0	Program calculated	Wall pier length at top of pier, L_p. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See "How the Program Calculates the Default Dimensions" in Shear Wall Design Technical Note 6 Wall Pier Design Section for more information. Inputting 0 means the item is to be program calculated.
DB1LeftTop	≥ 0	0	Length of the top of a user-defined edge member on the left side of a wall pier, $DB1_{left}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section.
DB1RightTop	≥ 0	Same as DB1-left-bot	Length of the top of a user-defined edge member on the right side of a wall pier, $DB1_{right}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section.
DB2LeftTop	≥ 0	0	Width of the top of a user-defined edge member on the left side of a wall pier, $DB2_{left}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section.
DB2RightTop	≥ 0	Same as DB2-left-bot	Width of the top of a user-defined edge member on the right side of a wall pier, $DB2_{right}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section.
Material	Any defined concrete material property	See "Material Properties" in Shear Wall Design Technical Note 6 Wall Pier Design Section	Material property associated with the pier.

Table 1 Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Edge Design PC-max	> 0	Specified in Preferences	Maximum ratio of compression reinforcing allowed in edge members, PC_{max}. See "Design Condition 1" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.
Edge Design PT-max	> 0	Specified in Preferences	Maximum ratio of tension reinforcing allowed in edge members, PT_{max}. See "Design Condition 1" in Shear Wall Design UBC97 Technical Note 14 Wall Pier Flexural Design.

LL Reduction Factor

If the LL Reduction Factor is program calculated, it is based on the live load reduction method chosen in the live load reduction preferences, which are set using the **Options menu > Preferences > Live Load Reduction** command. If you specify your own LL Reduction Factor, the program ignores any reduction method specified in the live load reduction preferences and simply calculates the reduced live load for a pier or spandrel by multiplying the specified LL Reduction Factor times the reducible live load.

Note that you can use the **Define menu > Static Load Cases** command to specify that a load case is a reducible live load.

Important Note: The LL reduction factor is ***not*** applied to any load combination that is included in a design load combination. For example, assume you have two static load cases labeled DL and RLL. DL is a dead load and RLL is a reducible live load.

Now assume that you create a design load combination named DESCOMB1 that includes DL and RLL. Then for design load combination DESCOMB1, the RLL load is multiplied by the LL reduction factor.

Next assume that you create a load combination called COMB2 that includes RLL. Now assume that you create a design load combination called

DESCOMB3 that included DL and COMB2. For design load combination DESCOMB3, the RLL load that is part of COMB2 is ***not*** multiplied by the LL reduction factor.

EQ Factor

The EQ (earthquake) factor is a multiplier that is typically applied to the earthquake load in a design load combination. Following are the five types of loads that can be included in a design load combination, along with an explanation of how the EQ factor is applied to each of the load types.

- **Static Load:** The EQ factor is applied to any static loads designated as a Quake-type load. The EQ factor is not applied to any other type of static load.

- **Response Spectrum Case:** The EQ factor is applied to all response spectrum cases.

- **Time History Case:** The EQ factor is applied to all time history cases.

- **Static Nonlinear Case:** The EQ factor is ***not*** applied to any static nonlinear cases.

- **Load Combination:** The EQ factor is ***not*** applied to any load combination that is included in a design load combination. For example, assume you have two static load cases labeled DL and EQ. DL is a dead load and EQ is a quake load.

  Now assume that you create a design load combination named DESCOMB1 that includes DL and EQ. For design load combination DESCOMB1, the EQ load is multiplied by the EQ factor.

  Next assume that you create a load combination called COMB2 that includes EQ. Now assume that you create a design load combination called DESCOMB3 that included DL and COMB2. For design load combination DESCOMB3, the EQ load that is part of COMB2 is ***not*** multiplied by the EQ factor.

The EQ factor allows you to design different members for different levels of earthquake loads in the same run. It also allows you to specify member-specific reliability/redundancy factors that are required by some codes. The ρ factor specified in Section 1630.1.1 of the 1997 UBC is an example of this.

User-Defined Edge Members

When defining a user-defined edge member, you must specify both a nonzero value for DB1 and a nonzero value for DB2. If either DB1 or DB2 is specified as zero, the edge member width is taken the same as the pier thickness and the edge member length is determined by the program.

Spandrel Design Overwrites

Table 2 Spandrel Design Overwrites

Spandrel Overwrite Item	Possible Values	Default Value	Spandrel Overwrite Description
Design this Spandrel	Yes or No	Yes	Toggle for design of the spandrel when you click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.
LL Reduction Factor	Program calculated, > 0	Program calculated	A reducible live load is multiplied by this factor to obtain the reduced live load. Entering 0 for this item means that it is program calculated. See the previous section herein entitled "LL Reduction Factor" for more information.
EQ Factor	≥ 0	1	Multiplier on earthquake loads. If 0 is entered for this item, the program resets it to the default value of 1 when the next design is run. See the previous section herein entitled "EQ Factor" for more information.
Design is Seismic	Yes or No	Yes	Toggle for design as seismic or nonseismic. Additional design checks are performed for seismic elements compared to nonseismic elements. Also, in some cases the strength reduction factors are different.
Length	Program calculated, or > 0	Program calculated	Wall spandrel length, L_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated.

Table 2 Spandrel Design Overwrites

Spandrel Overwrite Item	Possible Values	Default Value	Spandrel Overwrite Description
ThickLeft	Program calculated, or > 0	Program calculated	Wall spandrel thickness at left side of spandrel, t_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated.
DepthLeft	Program calculated, or > 0	Program calculated	Wall spandrel depth at left side of spandrel, h_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated.
CoverBotLeft	Program calculated, or > 0	Program calculated	Distance from bottom of spandrel to centroid of bottom reinforcing, $d_{r\text{-bot left}}$ on left side of beam. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated as $0.1h_s$.
CoverTopLeft	Program calculated, or > 0	Program calculated	Distance from top of spandrel to centroid of top reinforcing, $d_{r\text{-top left}}$ on left side of beam. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated as $0.1h_s$.
SlabWidthLeft	≥ 0	0	Slab width for T-beam at left end of spandrel, b_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section.
SlabDepthLeft	≥ 0	0	Slab depth for T-beam at left end of spandrel, d_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section.

Table 2 Spandrel Design Overwrites

Spandrel Overwrite Item	Possible Values	Default Value	Spandrel Overwrite Description
ThickRight	Program calculated, or > 0	Program calculated	Wall spandrel thickness at right side of spandrel, t_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated.
DepthRight	Program calculated, or > 0	Program calculated	Wall spandrel depth at right side of spandrel, h_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated.
CoverBotRight	Program calculated, or > 0	Program calculated	Distance from bottom of spandrel to centroid of bottom reinforcing, $d_{r\text{-bot right}}$ on right side of beam. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated as $0.1h_s$.
Cover-TopRight	Program calculated, or > 0	Program calculated	Distance from top of spandrel to centroid of top reinforcing, $d_{r\text{-top right}}$ on right side of beam. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section. Inputting 0 means the item is to be program calculated as $0.1h_s$.
SlabWidth-Right	≥ 0	0	Slab width for T-beam at right end of spandrel, b_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section.
SlabDepth-Right	≥ 0	0	Slab depth for T-beam at right end of spandrel, d_s. See Figure 1 of Shear Wall Design Technical Note 7 Wall Spandrel Design Section.

Table 2 Spandrel Design Overwrites

Spandrel Overwrite Item	Possible Values	Default Value	Spandrel Overwrite Description
Material	Any defined concrete material property	See "Default Design Material Property" in Shear Wall Design Technical Note 7 Wall Spandrel Design Section	Material property associated with the spandrel.
Consider Vc	Yes or No	Yes	Toggle switch to consider V_c (concrete shear capacity) when computing the shear capacity of the spandrel.

Making Changes in the Overwrites Form

To access the pier overwrites, select a pier and then click the **Design menu > Shear Wall Design > View/Revise Pier Overwrites** command. To access the spandrel overwrites, select a spandrel and then click the **Design menu > Shear Wall Design > View/Revise Spandrel Overwrites** command.

The pier or spandrel overwrites are displayed in the form with a column of check boxes and a two-column spreadsheet. The left column of the spreadsheet contains the name of the overwrite item. The right column of the spreadsheet contains the overwrites values.

Initially, the check boxes in the Pier or Spandrel Design form are all unchecked and all of the cells in the spreadsheet have a gray background to indicate that they are inactive and the items in the cells cannot be changed. The names of the overwrite items are displayed in the first column of the spreadsheet. The values of the overwrite items are visible in the second column of the spreadsheet if only one pier or spandrel was selected before the overwrites form was accessed. If multiple piers or spandrels were selected, no values show for the overwrite items in the second column of the spreadsheet.

After selecting one or multiple piers or spandrels, check the box to the left of an overwrite item to change it. Then left click in either column of the spreadsheet to activate a drop-down box or highlight the contents in the cell in the right column of the spreadsheet. If the drop-down box appears, select a value from the box. If the cell contents is highlighted, type in the desired value. The overwrite will reflect the change. You cannot change the values of the drop-down boxes.

When changes to the pier or spandrel overwrites have been completed, click the **OK** button to close the form. The program then changes all of the overwrite items whose associated check boxes are checked for the selected pier(s) or spandrel(s). You *must* click the **OK** button for the changes to be accepted by the program. If you click the **Cancel** button to exit the form, any changes made to the overwrites are ignored and the form is closed.

Technical Note 13
Design Load Combinations

This Technical Note defines the default concrete shear wall design load combinations. Use the default shear wall design load combinations, define your own combinations, or use both default and user-defined combinations. Modify the default design load combinations and delete them as necessary.

Note:

The program automatically creates code-specific design load combinations for shear wall design.

Default Design Load Combinations

The design load combinations automatically created by the program for concrete shear wall design are given by Equations 1 through 10.

$1.4\Sigma DL$ Eqn. 1

$1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL)$ Eqn. 2

$0.75[1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL) + 1.7WL]$ Eqn. 3

$0.75[1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL) - 1.7WL]$ Eqn. 4

$0.9\Sigma DL + 1.3WL$ Eqn. 5

$0.9\Sigma DL - 1.3WL$ Eqn. 6

$1.1\ [1.2\Sigma DL + 0.5(\Sigma LL + \Sigma RLL) + 1.0E]$ Eqn. 7

$1.1\ [1.2\Sigma DL + 0.5(\Sigma LL + \Sigma RLL) - 1.0E]$ Eqn. 8

$1.1\ (0.9\Sigma DL + 1.0E)$ Eqn. 9

$1.1\ (0.9\Sigma DL - 1.0E)$ Eqn. 10

In Equations 1 through 10,

ΣDL = The sum of all dead load (DL) load cases defined for the model.

ΣLL = The sum of all live load (LL) load cases defined for the model. Note that this includes roof live loads as well as floor live loads.

ΣRLL = The sum of all reducible live load (RLL) load cases defined for the model.

WL = Any single wind load (WL) load case defined for the model.

E = Any single earthquake load (E) load case defined for the model.

Dead Load Component

The dead load component of the default design load combinations consists of the sum of all dead loads multiplied by the specified factor. Individual dead load cases are not considered separately in the default design load combinations.

See the description of the earthquake load component later in this Technical Note for additional information.

Live Load Component

The live load component of the default design load combinations consists of the sum of all live loads, both reducible and unreducible, multiplied by the specified factor. Individual live load cases are not considered separately in the default design load combinations.

Wind Load Component

The wind load component of the default design load combinations consists of the contribution from a single wind load case. Thus, if multiple wind load cases are defined in the model, each of Equations 3 through 6 will contribute multiple design load combinations, one for each wind load case that is defined.

Earthquake Load Component

The earthquake load component of the default design load combinations consists of the contribution from a single earthquake load case. Thus, if multiple earthquake load cases are defined in the model, each of Equations 7 through 10 will contribute multiple design load combinations, one for each earthquake load case that is defined.

The earthquake load cases considered when creating the default design load combinations include all static load cases that are defined as earthquake loads and all response spectrum cases. Default design load combinations are not created for time history cases or for static nonlinear cases.

Design Load Combinations That Include a Response Spectrum

In this program, all response spectrum cases are assumed to be earthquake load cases. Default design load combinations are created that include the response spectrum cases.

The output from a response spectrum is all positive. *Any program shear wall design load combination that includes a response spectrum load case is checked for all possible combinations of signs on the response spectrum values.* Thus, when checking shear in a wall pier or a wall spandrel, the response spectrum contribution of shear to the design load combination is considered once as a positive shear and then a second time as a negative shear. Similarly, when checking moment in a wall spandrel, the response spectrum contribution of moment to the design load combination is considered once as a positive moment and then a second time as a negative moment. When checking the flexural behavior of a two-dimensional wall pier or spandrel, four possible combinations are considered for the contribution of response spectrum load to the design load combination. They are:

- +P and +M
- +P and -M
- -P and +M
- -P and -M

where P is the axial load in the pier and M is the moment in the pier. Similarly, eight possible combinations of P, M2 and M3 are considered for three-dimensional wall piers.

Note that based on the above, Equations 7 and 8 are redundant for a load combination with a response spectrum, and similarly, Equations 9 and 10 are redundant for a load combination with a response spectrum. For this reason, the program only creates default design load combinations based on Equations 7 and 9 for response spectra. Default design load combinations using Equations 8 and 10 are not created for response spectra.

Design Load Combinations that Include Time History Results

The default shear wall design load combinations do not include any time history results. To include time history forces in a design load combination, define the load combination yourself.

When your design load combination includes time history results, you can design for the envelope of those results, or you can do a design for each step of the time history. You specify the type of time history design in the shear wall design preferences. See Shear Wall Design UBC97 Technical Note 11 Preferences for more information.

When you design for the envelopes, the design is for the maximum of each response quantity (axial load, moment, etc.) as if they occurred simultaneously. Typically, this is not the realistic case, and in some instances, it may be unconservative. Designing for each step of a time history gives you the correct correspondence between different response quantities, but designing for each step can be very time consuming.

When the program gets the envelope results for a time history, it gets a maximum and a minimum value for each response quantity. Thus, for wall piers it gets maximum and minimum values of axial load, shear and moment; and for wall spandrels, it gets maximum and minimum values of shear and moment. For a design load combination in the program shear wall design module, any load combination that includes a time history load case in it is checked for all possible combinations of maximum and minimum time history design values. Thus, when checking shear in a wall pier or a wall spandrel, the time history contribution of shear to the design load combination is considered once as a maximum shear and then a second time as a minimum shear. Similarly, when checking moment in a wall spandrel, the time history contribution of moment to the design load combination is considered once as a maximum moment and then a second time as a minimum moment. When checking the flexural behavior of a wall pier, four possible combinations are considered for the contribution of time history load to the design load combination. They are:

- P_{max} and M_{max}

- P_{max} and M_{min}
- P_{min} and M_{max}
- P_{min} and M_{min}

where P is the axial load in the pier and M is the moment in the pier.

If a single design load combination has more than one time history case in it, that design load combination is designed for the envelopes of the time histories, regardless of what is specified for the Time History Design item in the preferences.

Design Load Combinations That Include Static Nonlinear Results

The default shear wall design load combinations do not include any static nonlinear results. To include static nonlinear results in a design load combination, define the load combination yourself.

If a design load combination includes a single static nonlinear case and nothing else, the design is performed for each step of the static nonlinear analysis. Otherwise, the design is only performed for the last step of the static nonlinear analysis.

ETABS® CSI

SHEAR WALL DESIGN UBC97

Technical Note 14
Wall Pier Flexural Design

Overview

This Technical Note describes how the program designs and checks concrete wall piers for flexural and axial loads using the 1997 UBC. The Technical Note is presented into three main sections. First we describe how the program *designs* piers that are specified by a Simplified Section. Next we describe how the program *checks* piers that are specified by a Section Designer Section. Then we describe how the program *designs* piers that are specified by a Section Designer Section.

For both designing and checking piers, it is important that you understand the local axis definition for the pier. The default local pier axes can be described as follows: When looking at a wall pier in elevation view, the positive, local 1-axis is vertical and pointing up, parallel to the height of the wall pier. The positive, local 2-axis is horizontal and pointing to the right, parallel to the length of the wall. The positive, local 3-axis is perpendicular to the surface of the wall pier and pointing out. Changes can be made to the local axes assignments using the **Assign** menu.

Designing a Simplified Pier Section

This section discusses how the program designs a pier that is assigned a simplified section. The geometry associated with the simplified section is illustrated in "Simplified Pier Design Dimensions and Properties" in Shear Wall Design Technical Note 6 Wall Pier Design Sections. The pier geometry is defined by a length, thickness and size of the edge members at each end of the pier (if any).

If no specific edge member dimensions have been specified by the user, the program assumes that the edge member is the same width as the wall, and the program determines the required length of the edge member. In all cases, whether the edge member size is user-specified or program-determined, the program reports the required area of reinforcing steel at the center of the edge member. This section describes how the program-determined length of the edge member is determined and how the program calculates the required reinforcing at the center of the edge member.

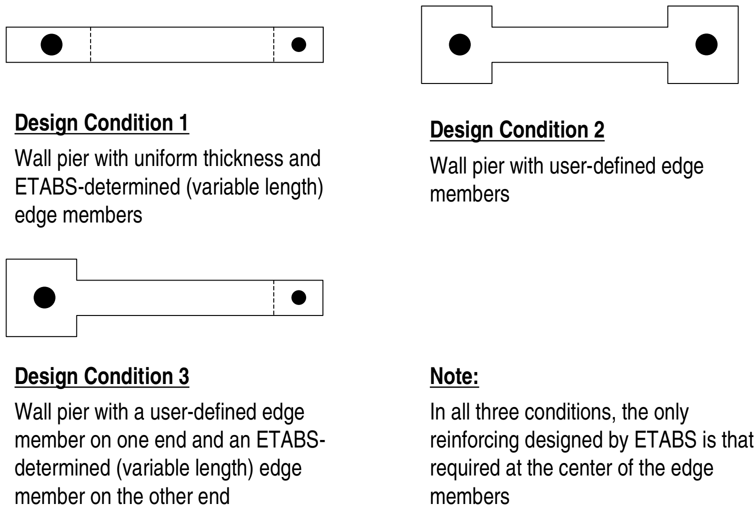


Figure 1: Design Conditions for Simplified Wall Piers

There are three possible design conditions for a simplified wall pier. These conditions, illustrated in Figure 1, are:

1. The wall pier has program-determined (variable length and fixed width) edge members on each end.

2. The wall pier has user-defined (fixed length and width) edge members on each end.

3. The wall pier has a program-determined (variable length and fixed width) edge member on one end and a user-defined (fixed length and width) edge member on the other end.

Design Condition 1

Design condition 1 applies to a wall pier with uniform design thickness and program-determined edge member length. For this design condition, the design algorithm focuses on determining the required size (length) of the edge members while limiting the compression and tension reinforcing located at the center of the edge members to user-specified maximum ratios. The maximum ratios are specified in the shear wall design preferences and the pier design overwrites as Edge Design PC-Max and Edge Design PT-Max.

Consider the wall pier shown in Figure 2. For a given design section, say the top of the wall pier, the wall pier for a given design load combination is designed for a factored axial force $P_{u\text{-}top}$ and a factored moment $M_{u\text{-}top}$.

The program initiates the design procedure by assuming an edge member at the left end of the wall of thickness t_p and width $B_{1\text{-}left}$, and an edge member at the right end of the wall of thickness t_p and width $B_{1\text{-}right}$. Initially $B_{1\text{-}left}$ = $B_{1\text{-}right}$ = t_p.

The moment and axial force are converted to an equivalent force set $P_{left\text{-}top}$ and $P_{right\text{-}top}$ using the relationships shown in Equations 1a and 1b. (Similar equations apply at the bottom of the pier).

$$P_{left-top} = \frac{P_{u-top}}{2} + \frac{M_{u-top}}{\left(L_p - 0.5B_{1-left} - 0.5B_{1-right}\right)} \qquad \text{Eqn. 1a}$$

$$P_{right-top} = \frac{P_{u-top}}{2} - \frac{M_{u-top}}{\left(L_p - 0.5B_{1-left} - 0.5B_{1-right}\right)} \qquad \text{Eqn. 1b}$$

For any given loading combination, the net values for $P_{left\text{-}top}$ and $P_{right\text{-}top}$ could be tension or compression.

Note that for dynamic loads, $P_{left\text{-}top}$ and $P_{right\text{-}top}$ are obtained at the modal level and the modal combinations are made, before combining with other loads. Also for design loading combinations involving SRSS, the $P_{left\text{-}top}$ and $P_{right\text{-}top}$ forces are obtained first for each load case before the combinations are made.

If any value of $P_{left\text{-}top}$ or $P_{right\text{-}top}$ is tension, the area of steel required for tension, A_{st}, is calculated as:

$$A_{st} = \frac{P}{\phi_b f_y} \qquad \text{Eqn. 2}$$

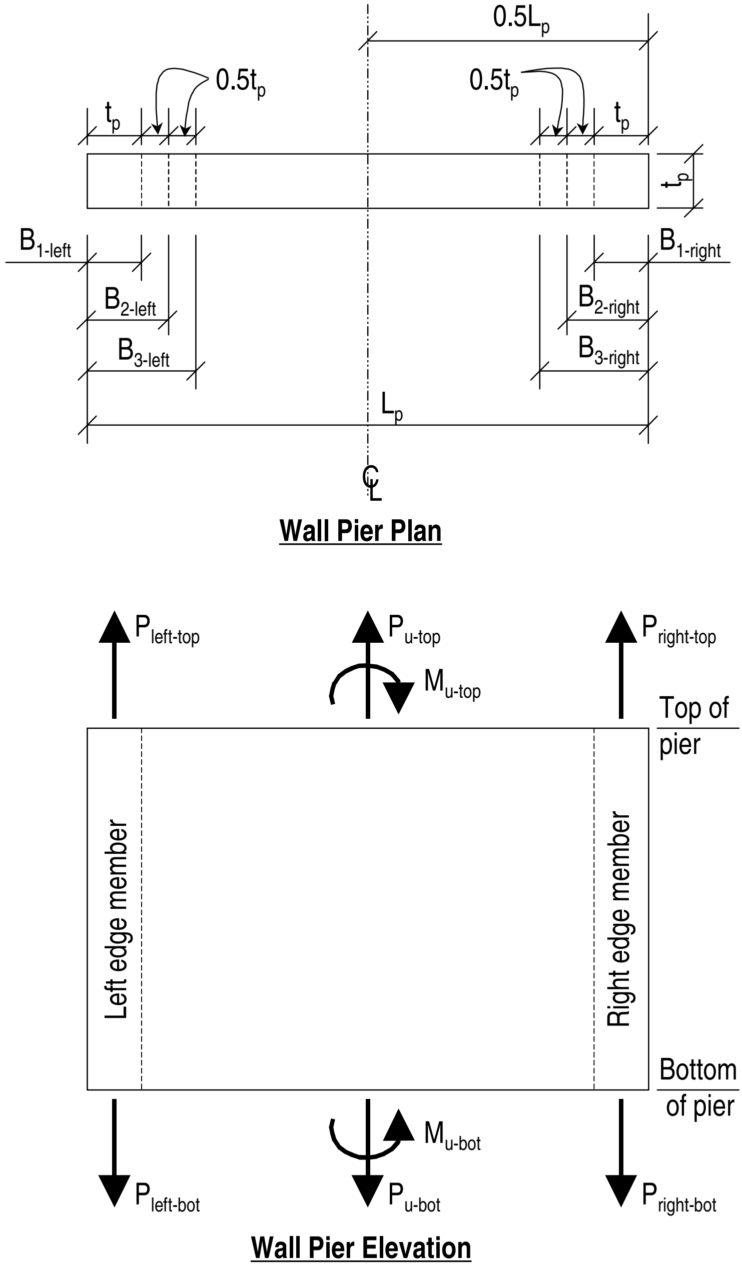


Figure 2: Wall Pier for Design Condition 1

If any value of $P_{left-top}$ or $P_{right-top}$ is compression, for section adequacy, the area of steel required for compression, A_{sc}, must satisfy the following relationship.

$$\text{Abs}(P) = (\text{Pmax Factor})\phi_c\,[0.85f'_c\,(A_g - A_{sc}) + f_y A_{sc}] \qquad \text{Eqn. 3}$$

where P is either $P_{left-top}$ or $P_{right-top}$, $A_g = t_p B_1$ and the Pmax Factor is defined in the shear wall design preferences (the default is 0.80). In general, we recommend that you use the default value. From Equation 3,

$$A_{sc} = \frac{\dfrac{\text{Abs}(P)}{(\text{Pmax Factor})\,\varphi_c} - 0.85f'_c A_g}{f_y - 0.85f'_c} \qquad \text{Eqn. 4}$$

If A_{sc} calculates as negative, no compression reinforcing is needed.

The maximum tensile reinforcing to be packed within the t_p times B_1 concrete edge member is limited by:

$$A_{st\text{-}max} = PT_{max} t_p B_1 \qquad \text{Eqn. 5}$$

Similarly, the compression reinforcing is limited by:

$$A_{sc\text{-}max} = PC_{max} t_p B_1 \qquad \text{Eqn. 6}$$

If A_{st} is less than or equal to A_{st-max} and A_{sc} is less than or equal to A_{sc-max}, the program will proceed to check the next loading combination; otherwise the program will increment the appropriate B_1 dimension (left, right or both depending on which edge member is inadequate) by one-half of the wall thickness to B_2 (i.e., $1.5t_p$) and calculate new values for $P_{left-top}$ and $P_{right-top}$ resulting in new values of A_{st} and A_{sc}. This iterative procedure continues until A_{st} and A_{sc} are within the allowed steel ratios for all design load combinations.

If the value of the width of the edge member B increments to where it reaches a value larger than or equal to $L_p/2$, the iteration is terminated and a failure condition is reported.

This design algorithm is an approximate but convenient algorithm. Wall piers that are declared overstressed using this algorithm could be found to be adequate if the reinforcing steel is user-specified and the wall pier is accurately evaluated using interaction diagrams.

Design Condition 2

Design condition 2 applies to a wall pier with user-specified edge members at each end of the pier. The size of the edge members is assumed to be fixed, that is, the program does not modify them. For this design condition, the design algorithm determines the area of steel required in the center edge members and checks if that area gives reinforcing ratios less than the user-specified maximum ratios. The design algorithm used is the same as described for condition 1; however, no iteration is required.

Design Condition 3

Design condition 3 applies to a wall pier with a user-specified (fixed dimension) edge member at one end of the pier and a variable length (program-determined) edge member at the other end. The width of the variable length edge member is equal to the width of the wall.

The design is similar to that which has previously been described for design conditions 1 and 2. The size of the user-specified edge member is not changed. Iteration only occurs on the size of the variable length edge member.

Checking a General or Uniform Reinforcing Pier Section

When you specify that a General Reinforcing or a Uniform Reinforcing pier section is to be checked, the program creates an interaction surface for that pier and uses that interaction surface to determine the critical flexural demand/capacity ratio for the pier. This section describes how the program generates the interaction surface for the pier and how it determines the demand/capacity ratio for a given design load combination.

Note:

In this program, the interaction surface is defined by a series of PMM interaction curves that are equally spaced around a 360 degree circle.

Interaction Surface

General

In this program, a three-dimensional interaction surface is defined with reference to the P, M2 and M3 axes. The surface is developed using a series of interaction curves that are created by rotating the direction of the pier neutral axis in equally spaced increments around a 360 degree circle. For example, if 24 PMM curves are specified (the default), there is one curve every 360°/24 curves = 15°. Figure 3 illustrates the assumed orientation of the pier neutral axis and the associated sides of the neutral axis where the section is in tension (designated T in the figure) or compression (designated C in the figure) for various angles.

Note that the orientation of the neutral axis is the same for an angle of θ and $\theta + 180°$. Only the side of the neutral axis where the section is in tension or compression changes. We recommend that you use 24 interaction curves (or more) to define a three-dimensional interaction surface.

Each PMM interaction curve that makes up the interaction surface is numerically described by a series of discrete points connected by straight lines. The coordinates of these points are determined by rotating a plane of linear strain about the neutral axis on the section of the pier. Details of this process are described later in this Technical Note in the section entitled "Details of the Strain Compatibility Analysis."

By default, 11 points are used to define a PMM interaction curve. You can change this number in the preferences, specifying any odd number of points greater than or equal to 11, to be used in creating the interaction curve. If you input an even number for this item in the preferences, the program will increment up to the next higher odd number.

Note that when creating an interaction surface for a two-dimensional wall pier, the program considers only two interaction curves—the 0° curve and the 180° curve—regardless of the number of curves specified in the preferences. Furthermore, only moments about the M3 axis are considered for two-dimensional walls.

Formulation of the Interaction Surface

The formulation of the interaction surface in this program is based consistently on the basic principles of ultimate strength design given in Sections 1910.2 and 1910.3 of the 1997 UBC.

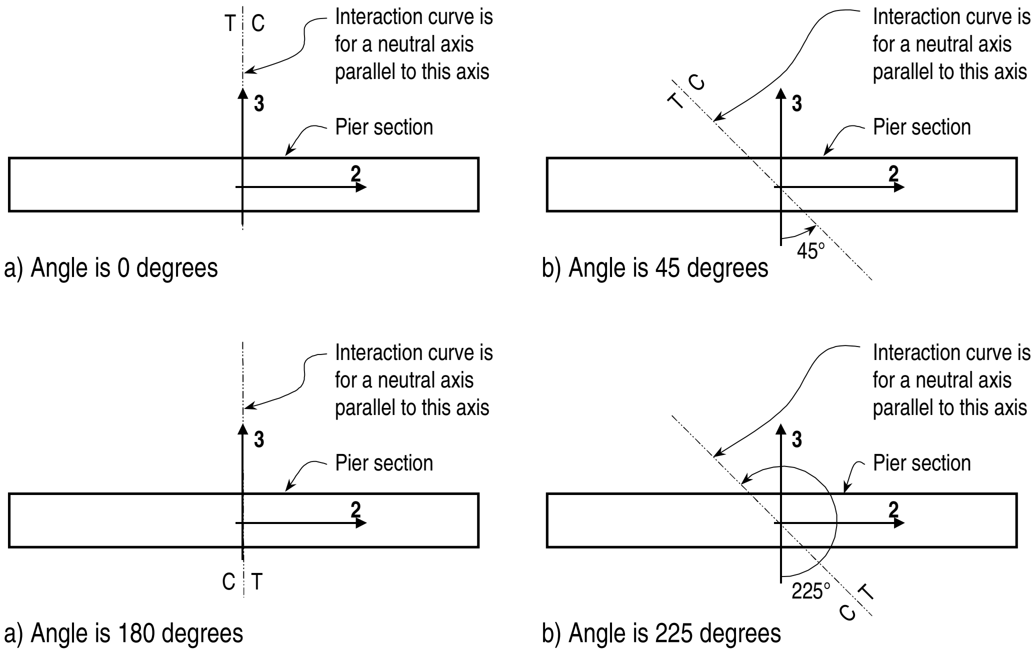


Figure 3: Orientation of the Pier Neutral Axis for Various Angles

The program uses the requirements of force equilibrium and strain compatibility to determine the nominal axial load and moment strength (P_n, $M2_n$, $M3_n$) of the wall pier. This nominal strength is then multiplied by the appropriate strength reduction factor, ϕ, to obtain the design strength (ϕP_n, $\phi M2_n$, $\phi M3_n$) of the pier. For the pier to be deemed adequate, the required strength (P_u, $M2_u$, $M3_u$) must be less than or equal to the design strength, as indicated in Equation 7.

$$(P_u, M2_u, M3_u) \le (\phi P_n, \phi M2_n, \phi M3_n) \qquad \text{Eqn. 7}$$

The effects of the strength reduction factor, ϕ, are included in the generation of the interaction curve. The strength reduction factor, ϕ, for high axial compression, with or without moment, is by default assumed to be equal to ϕ_c. For low values of axial compression, ϕ is increased linearly from ϕ_c to ϕ_b as the required axial strength, $P_u = \phi P_n$, decreases from the smaller of $0.10f'_cA_g$ or ϕP_b to zero, where:

ϕ_c = Strength reduction factor for axial compression in a wall pier. The default value is 0.70.

ϕ_b = Strength reduction factor for bending. The default value is 0.90.

P_b = The axial load at the balanced strain condition where the tension reinforcing reaches the strain corresponding to its specified yield strength, f_y, just as the concrete reaches its assumed ultimate strain of 0.003.

Note:

Strength reduction factors are specified in the shear wall design preference.

In cases involving axial tension, the strength reduction factor, ϕ, is by default equal to ϕ_b. You can revise the strength reduction factors ϕ_c and ϕ_b in the preferences and the overwrites.

The theoretical maximum compressive force that the wall pier can carry, assuming the ϕ_c factor is equal to 1, is designated P_{oc} and is given by Equation 8.

$$P_{oc} = [0.85f'_c\,(A_g - A_s) + f_yA_s] \qquad \text{Eqn. 8}$$

The theoretical maximum tension force that the wall pier can carry, assuming the ϕ_b factor is equal to 1, is designated P_{ot} and is given by Equation 9.

$$P_{ot} = f_yA_s \qquad \text{Eqn. 9}$$

If the wall pier geometry and reinforcing is symmetrical in plan, the moments associated with both P_{oc} and P_{ot} are zero. Otherwise, there will be a moment associated with both P_{oc} and P_{ot}.

The 1997 UBC limits the maximum compressive design strength, ϕ_cP_n, to the value given by P_{max} in Equation 10.

$$P_{max} = 0.80\phi_cP_{oc} = 0.80\phi[0.85f'_c\,(A_g - A_s) + f_yA_s] \qquad \text{Eqn. 10}$$

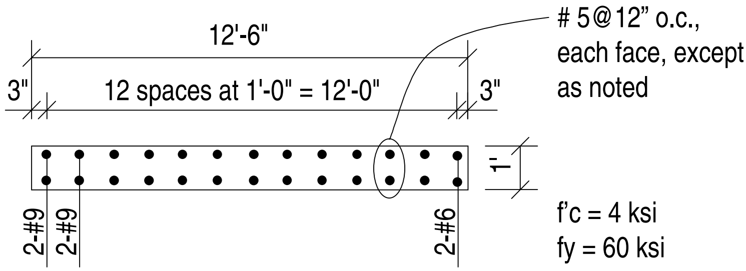


Figure 4: Example Two-Dimensional Wall Pier With Unsymmetrical Reinforcing

Note that the equation defining P_{max} reduces P_{oc} not only by a strength reduction factor, ϕ_c, but also by an additional factor of 0.80. In the preferences, this factor is called the Pmax Factor, and you can specify different values for it if desired. In all 1997 UBC code designs, it is prudent to consider this factor to be 0.80 as required by the code.

Note:

You can specify the number of points to be used for creating interaction diagrams in the shear wall preferences and overwrites.

As previously mentioned, by default, 11 points are used to define a single interaction curve. When creating a single interaction curve, the program includes the points at P_b, P_{oc} and P_{ot} on the interaction curve. Half of the remaining number of specified points on the interaction curve occur between P_b and P_{oc} at approximately equal spacing along the ϕP_n axis. The other half of the remaining number of specified points on the interaction curve occur between P_b and P_{ot} at approximately equal spacing along the ϕP_n axis.

Figure 4 shows a plan view of an example two-dimensional wall pier. Notice that the concrete is symmetrical but the reinforcing is not symmetrical in this example. Figure 5 shows several interaction surfaces for the wall pier illustrated in Figure 4. Note the following about Figure 5:

- Because the pier is two-dimensional, the interaction surface consists of two interaction curves. One curve is at 0° and the other is at 180°. Only M3 moments are considered because this is a two-dimensional example.

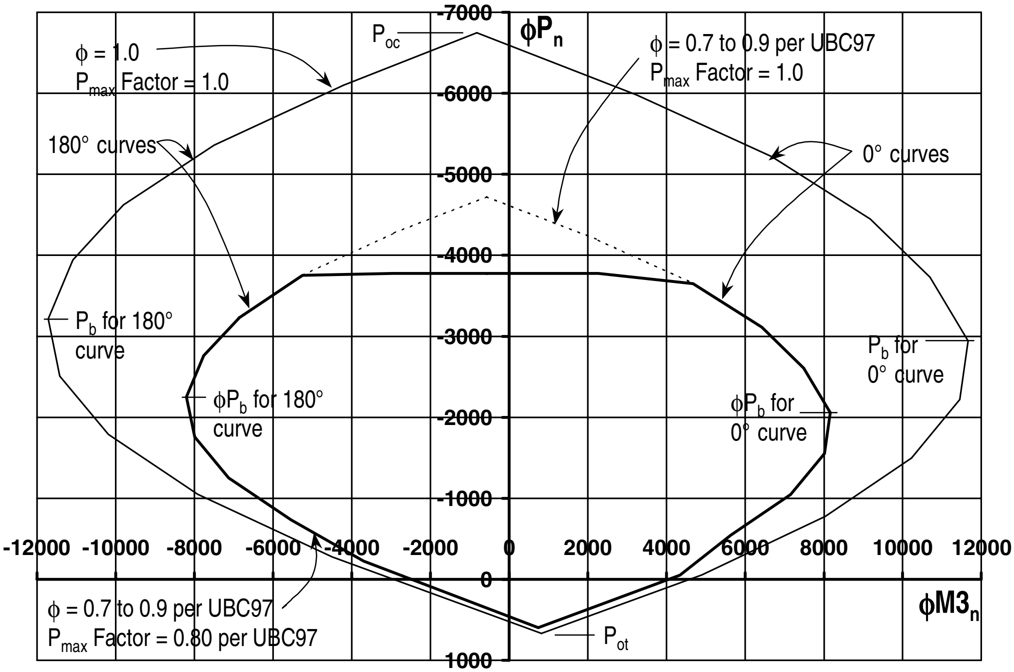


Figure 5: Interaction Curves for Example Wall Pier Shown in Figure 4

- In this program, compression is negative and tension is positive.
- The 0° and 180° interaction curves are not symmetric because the wall pier reinforcing is not symmetric.
- The smaller interaction surface (drawn with a heavier line) has both the strength reduction factors and the Pmax Factor, as specified by the 1997 UBC.
- The dashed line shows the effect of setting the Pmax Factor to 1.0.
- The larger interaction surface has both the strength reduction factor and the Pmax Factor set to 1.0.
- The interaction surfaces shown are created using the default value of 11 points for each interaction curve.

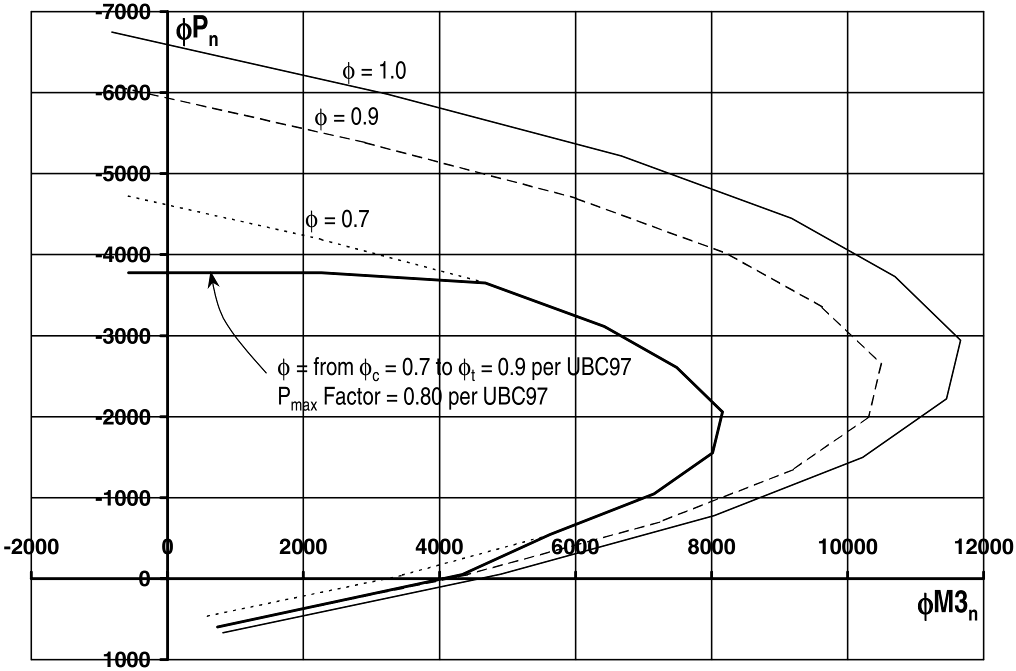


Figure 6: Interaction Curves for Example Wall Pier Shown in Figure 4

Figure 6 shows the 0° interaction curves for the wall pier illustrated in Figure 4. Additional interaction curves are also added to Figure 6. The smaller, heavier curve in Figure 6 has the strength reduction factor and the Pmax Factor as specified in the 1997 UBC. The other three curves, which are plotted for ϕ = 0.7, 0.9 and 1.0, all have Pmax Factors of 1.0. The purpose of showing these interaction curves is to explain how the program creates the interaction curve. Recall that the strength reduction factors 0.7 and 0.9 are actually ϕ_c and ϕ_b, and that their values can be revised in the overwrites if desired.

Details of the Strain Compatibility Analysis

As previously mentioned, the program uses the requirements of force equilibrium and strain compatibility to determine the nominal axial load and moment strength (P_n, $M2_n$, $M3_n$) of the wall pier. The coordinates of these points are determined by rotating a plane of linear strain on the section of the wall pier.

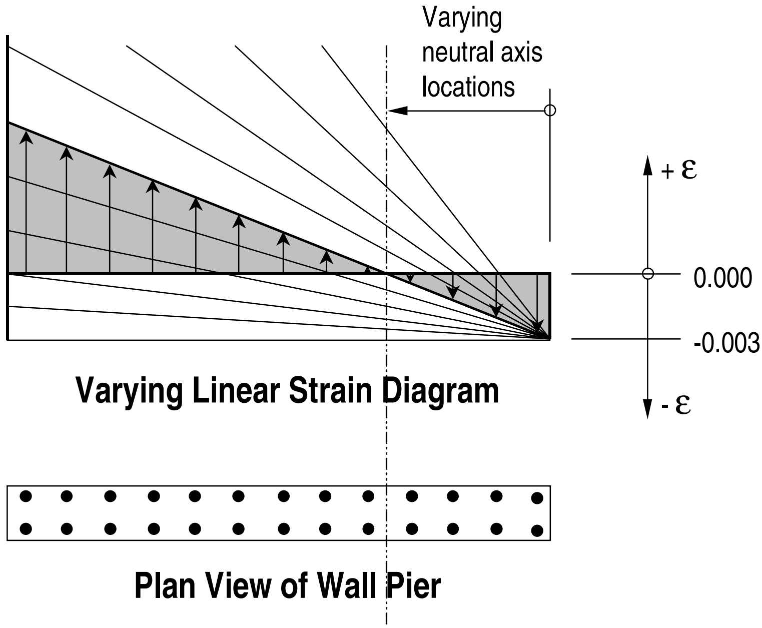


Figure 7: Varying Planes of Linear Strain

Figure 7 illustrates varying planes of linear strain such as those that the program considers on a wall pier section for a neutral axis orientation angle of 0 degrees. In these planes, the maximum concrete strain is always taken as -0.003 and the maximum steel strain is varied from -0.003 to plus infinity. (Recall that in this program compression is negative and tension is positive.) When the steel strain is -0.003, the maximum compressive force in the wall pier, P_{oc}, is obtained from the strain compatibility analysis. When the steel strain is plus infinity, the maximum tensile force in the wall pier, P_{ot}, is obtained. When the maximum steel strain is equal to the yield strain for the reinforcing (e.g., 0.00207 for f_y = 60 ksi), P_b, is obtained.

Figure 8 illustrates the concrete wall pier stress-strain relationship that is obtained from a strain compatibility analysis of a typical plane of linear strain shown in Figure 7.

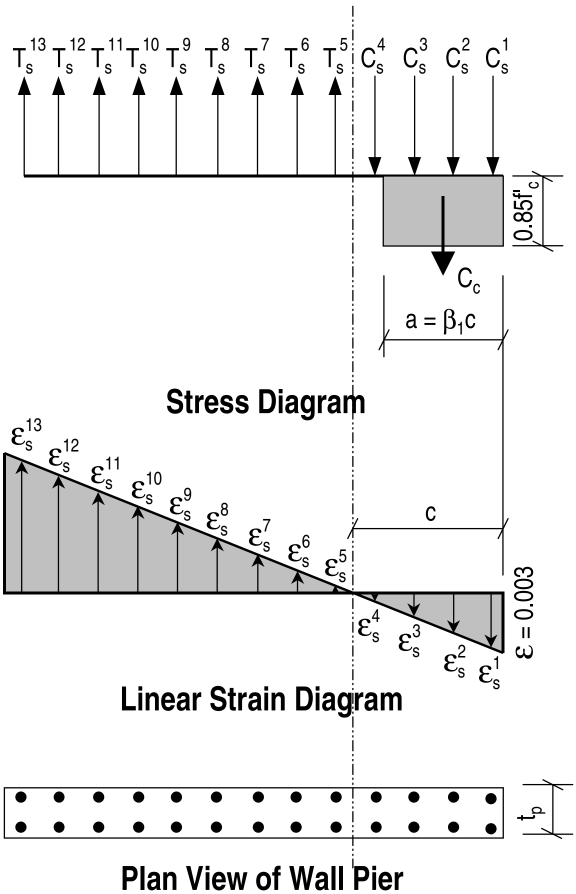


Figure 8: Wall Pier Stress-Strain Relationship

In Figure 8 the compressive stress in the concrete, C_c, is calculated using Equation 11.

$$C_c = 0.85f'_c\beta_1 c t_p \qquad \text{Eqn. 11}$$

In Figure 7, the value for maximum strain in the reinforcing steel is assumed. Then the strain in all other reinforcing steel is determined based on the assumed plane of linear strain. Next the stress in the reinforcing steel is calculated using Equation 12, where ε_s is the strain, E_s is the modulus of elasticity, σ_s is the stress, and f_y is the yield stress of the reinforcing steel.

$$\sigma_s = \varepsilon_s E_s \leq f_y \qquad \text{Eqn. 12}$$

The force in the reinforcing steel (T_s for tension or C_s for compression) is calculated using Equation 13 where:

$$T_s \text{ or } C_s = \sigma_s A_s \qquad \text{Eqn. 13}$$

For the given distribution of strain, the value of ϕP_n is calculated using Equation 14.

$$\phi P_n = \phi(\Sigma T_s - C_c - \Sigma C_s) \leq P_{max} \qquad \text{Eqn. 14}$$

In Equation 14, the tensile force T_s and the compressive forces C_c and C_s are all positive. If ϕP_n is positive, it is tension, and if it is negative, it is compression. The term P_{max} is calculated using Equation 10.

The value of $\phi M2_n$ is calculated by summing the moments resulting from all of the forces about the pier local 2-axis. Similarly, the value of $\phi M3_n$ is calculated by summing the moments resulting from all of the forces about the pier local 3-axis. The forces whose moments are summed to determine $\phi M2_n$ and $\phi M3_n$ are ϕP_n, ϕC_c, all of the ϕT_s forces and all of the ϕC_s forces.

The ϕP_n, $\phi M2_n$ and $\phi M3_n$ values calculated as described above make up one point on the wall pier interaction diagram. Additional points on the diagram are obtained by making different assumptions for the maximum steel stress; that is, considering a different plane of linear strain, and repeating the process.

When one interaction curve is complete, the next orientation of the neutral axis is assumed and the points for the associated new interaction curve are calculated. This process continues until the points for all of the specified curves have been calculated.

Again, note that for two-dimensional pier design M2 is ignored.

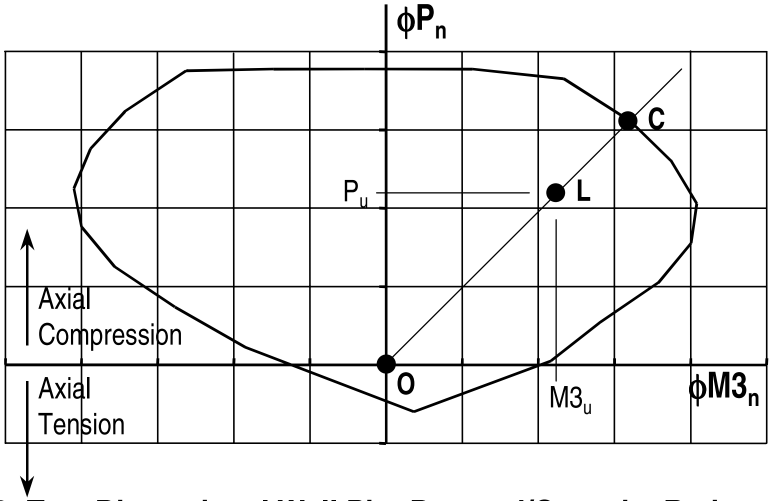


Figure 9: Two-Dimensional Wall Pier Demand/Capacity Ratio

Wall Pier Demand/Capacity Ratio

Refer to Figure 9, which shows a typical two-dimensional wall pier interaction diagram. The forces obtained from a given design load combination are P_u and $M3_u$. The point L, defined by (P_u, $M3_u$), is placed on the interaction diagram as shown in the figure. If the point lies within the interaction curve, the wall pier capacity is adequate. If the point lies outside of the interaction curve, the wall pier is overstressed.

As a measure of the stress condition in the wall pier, the program calculates a stress ratio. The ratio is achieved by plotting the point L and determining the location of point C. The point C is defined as the point where the line OL (extended outward if needed) intersects the interaction curve. The demand/capacity ratio, D/C, is given by D/C = OL / OC where OL is the "distance" from point O (the origin) to point L and OC is the "distance" from point O to point C. Note the following about the demand/capacity ratio:

- If OL = OC (or D/C = 1), the point (P_u, $M3_u$) lies on the interaction curve and the wall pier is stressed to capacity.
- If OL < OC (or D/C < 1), the point (P_u, $M3_u$) lies within the interaction curve and the wall pier capacity is adequate.

- If OL > OC (or D/C > 1), the point (P_u, $M3_u$) lies outside of the interaction curve and the wall pier is overstressed.

The wall pier demand/capacity ratio is a factor that gives an indication of the stress condition of the wall with respect to the capacity of the wall.

The demand/capacity ratio for a three-dimensional wall pier is determined in a similar manner to that described here for two-dimensional piers.

Designing a General Reinforcing Pier Section

When you specify that a General Reinforcing pier section is to be designed, the program creates a series of interaction surfaces for the pier based on the following items:

1. The size of the pier as specified in Section Designer.

2. The location of the reinforcing specified in Section Designer.

3. The size of each reinforcing bar specified in Section Designer *relative* to the size of the other bars.

The interaction surfaces are developed for eight different ratios of reinforcing steel area to pier area. The pier area is held constant and the rebar area is modified to obtain these different ratios; however, the *relative* size (area) of each rebar compared to the other bars is always kept constant.

The smallest of the eight reinforcing ratios used is that specified in the shear wall design preferences as Section Design IP-Min. Similarly, the largest of the eight reinforcing ratios used is that specified in the shear wall design preferences as Section Design IP-Max.

The eight reinforcing ratios used are the maximum and the minimum ratios plus six more ratios. The spacing between the reinforcing ratios is calculated as an increasing arithmetic series in which the space between the first two ratios is equal to one-third of the space between the last two ratios.

Table 1 illustrates the spacing, both in general terms and for a specific example, when the minimum reinforcing ratio, IPmin, is 0.0025 and the maximum, IPmax, is 0.02.

Table 1 The Eight Reinforcing Ratios Used by the Program

Curve	Ratio	Example
1	IPmin	0.0025
2	$\text{IPmin} + \frac{\text{IPmax} - \text{IPmin}}{14}$	0.0038
3	$\text{IPmin} + \frac{7}{3}\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0054
4	$\text{IPmin} + 4\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0075
5	$\text{IPmin} + 6\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0100
6	$\text{IPmin} + \frac{25}{3}\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0129
7	$\text{IPmin} + 11\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0163
8	IPmax	0.0200

After the eight reinforcing ratios have been determined, the program develops interaction surfaces for all eight of the ratios using the process described earlier in this Technical Note in the section entitled "Checking a Section Designer Pier Section."

Next, for a given design load combination, the program generates a demand/capacity ratio associated with each of the eight interaction surfaces. The program then uses linear interpolation between the eight interaction surfaces to determine the reinforcing ratio that gives an demand/capacity ratio of 1 (actually the program uses 0.99 instead of 1). This process is repeated for all design load combinations and the largest required reinforcing ratio is reported.

Design of a Uniform Reinforcing pier section is similar to that described herein for the General Reinforcing section.

Technical Note 15
Wall Pier Shear Design

This Technical Note describes how the program designs each leg of concrete wall piers for shear using the 1997 UBC. Note that in this program you cannot specify shear reinforcing and then have the program check it. The program only designs the pier for shear and reports how much shear reinforcing is required. The shear design is performed at stations at the top and bottom of the pier.

General

The wall pier shear reinforcing is designed for each of the design load combinations. The following steps are involved in designing the shear reinforcing for a particular wall pier section for a particular design loading combination.

1. Determine the factored forces P_u, M_u and V_u that are acting on the wall pier section. Note that P_u and M_u are required for the calculation of V_c.

2. Determine the shear force, V_c, that can be carried by the concrete.

3. Determine the required shear reinforcing to carry the balance of the shear force.

Step 1 needs no further explanation. The following two sections describe in detail the algorithms associated with the Steps 2 and 3.

Note:

The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this Technical Note is a shear strength reduction factor that applies to lightweight concrete. It is equal to 1 for normal weight concrete. This factor is specified in the concrete material properties.

Determine the Concrete Shear Capacity

Given the design force set P_u, M_u and V_u acting on a wall pier section, the shear force carried by the concrete, V_c, is calculated using Equations 1 and 2.

$$V_c = 3.3R_{LW}\sqrt{f'_c}\ t_p(0.8L_p) - \frac{P_u(0.8L_p)}{4L_p} \qquad \text{Eqn. 1}$$

where V_c may not be greater than

$$V_c = \left[0.6R_{LW}\sqrt{f'_c} + \frac{L_p\left(1.25R_{LW}\sqrt{f'_c} - 0.2\dfrac{P_u}{L_p t_p}\right)}{Abs\left(\dfrac{M_u}{V_u}\right) - \dfrac{L_p}{2}}\right] t_p(0.8L_p) \qquad \text{Eqn. 2}$$

Equation 2 doesn't apply if $Abs\left(\frac{M_u}{V_u}\right) - \frac{L_p}{2}$ is negative or zero, or if V_u is zero.

If the tension is large enough that Equation 1 or Equation 2 results in a negative number, V_c is set to zero.

Note that these equations are identical to Equations 11-31 and 11-32 in Chapter 19, Section 1911.10.6 of the 1997 UBC with the UBC dimension "d" set equal to 0.8*L_p. The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this Technical Note is a shear strength reduction factor that applies to lightweight concrete. It is equal to 1 for normal weight concrete. This factor is specified in the concrete material properties.

Recall that in the program tension is positive; thus, the negative sign on the second term in Equation 1 is consistent with Equation 11-31 in the 1997 UBC. Similarly, the negative sign on the second term in the parenthesis of Equation 2 is consistent with Equation 11-32 in the 1997 UBC.

Note:

You can set the output units for the distributed shear reinforcing in the shear wall design preferences.

Determine the Required Shear Reinforcing

Seismic and Nonseismic Piers

Given V_u and V_c, Equation 3 provides the required shear reinforcing in area per unit length (e.g., square inches per inch) for both seismic and nonseismic wall piers (as indicated by the "Design is Seismic" item in the pier design overwrites). Note that additional requirements for seismic piers are provided later in this section.

$$A_v = \frac{\dfrac{Abs(V_u)}{\phi} - V_c}{f_{ys}\,(0.8L_p)} \qquad \text{Eqn. 3}$$

where,

$V_n = \dfrac{Abs\,(V_u)}{\phi}$ must not exceed $10R_{LW}\sqrt{f'_c}\; t_p(0.8L_p)$ per 1997 UBC Section 1911.10.3.

In Equation 3, the term ϕ is equal to ϕ_{vns} for nonseismic piers and to ϕ_{vs} for seismic piers. The ϕ (phi) factors are specified in the shear wall design preferences.

Additional Requirements for Seismic Piers

For shear design of seismic wall piers, the following additional requirements are also checked.

The nominal shear strength of the wall pier is limited to:

$$V_n = \left(2R_{LW}\sqrt{f'_c} + \frac{A_v}{t_p} f_{ys}\right) L_p t_p \qquad \text{Eqn. 4}$$

where,

$V_n = \dfrac{Abs\,(V_u)}{\phi_{vs}}$ must not exceed $8R_{LW}\sqrt{f'_c}\; t_p L_p$ per 1997 UBC Section 1921.6.5.6.

A_v is the horizontal shear reinforcing per unit vertical length (height) of the wall pier. Equation 4 is based on Equation 21-6 in Section 1921.6.5.2 of the 1997 UBC. Since $V_u = \phi_{vs} V_n$, A_v can be calculated as shown in Equation 5.

$$A_v = \frac{\dfrac{\text{Abs}\,(V_u)}{\phi_{vs}} - 2R_{LW}\sqrt{f'_c}\; L_p t_p}{f_{ys} L_p} \qquad \text{Eqn. 5}$$

Note that the program conservatively uses 1997 UBC Equation 21-6 (Section 1921.6.5.2) in all cases, even in cases where 1997 UBC Equation 21-7 (Section 1921.6.5.3) might be applicable. This is a conservative assumption. Also note that the maximum wall pier nominal shear force is limited by the program to $8R_{LW}\sqrt{f'_c}\; t_p L_p$ not $10R_{LW}\sqrt{f'_c}\; t_p L_p$.

Technical Note 16
Spandrel Flexural Design

This Technical Note describes how the program designs concrete shear wall spandrels for flexure using the 1997 UBC requirements. This program allows consideration of rectangular sections and T-beam sections for shear wall spandrels. Note that the program designs spandrels at stations located at the ends of the spandrel. No design is performed at the center (midlength) of the spandrel.

General

The spandrel flexural reinforcing is designed for each of the design load combinations. The required area of reinforcing for flexure is calculated and reported only at the ends of the spandrel beam.

In this program, wall spandrels are designed for major direction flexure and shear only. Effects caused by any axial forces, minor direction bending, torsion or minor direction shear that may exist in the spandrels must be investigated by the user independent of the program.

The following steps are involved in designing the flexural reinforcing for a particular wall spandrel section for a particular design loading combination at a particular station.

- Determine the maximum factored moment M_u.
- Determine the required flexural reinforcing.

These steps are described in the following sections.

Determine the Maximum Factored Moments

In the design of flexural reinforcing for spandrels, the factored moments for each design load combination at a particular beam station are first obtained.

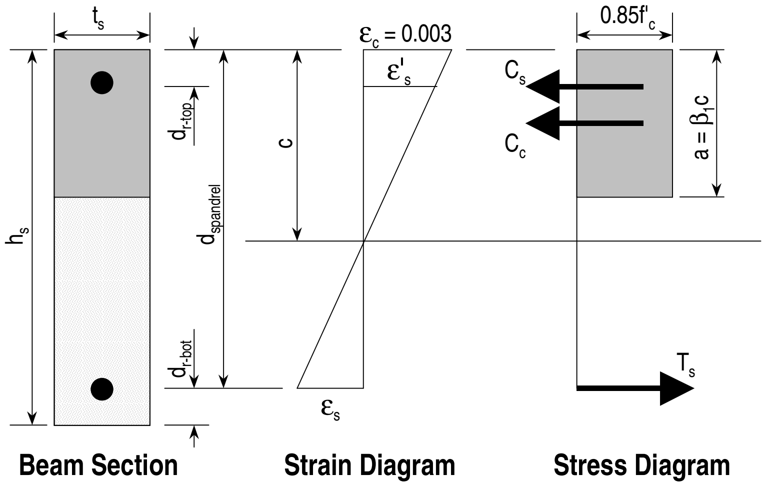


Figure 1: Rectangular spandrel beam design, positive moment

The beam section is then designed for the maximum positive and the maximum negative factored moments obtained from all of the design load combinations.

Determine the Required Flexural Reinforcing

In this program, negative beam moments produce top steel. In such cases, the beam is always designed as a rectangular section.

In this program, positive beam moments produce bottom steel. In such cases, the beam may be designed as a rectangular section, or as a T-beam section. You indicate that a spandrel is to be designed as a T-beam by providing appropriate slab width and depth dimensions in the spandrel design overwrites.

The flexural design procedure is based on a simplified rectangular stress block, as shown in Figure 1. It is assumed that the compression carried by the concrete is less than or equal to 0.75 times that which can be carried at the balanced condition. When the applied moment exceeds the moment capacity at 0.75 times the balanced condition, the program calculates an area of compression reinforcement assuming that the additional moment is carried by compression reinforcing and additional tension reinforcing.

The procedure used by the program for both rectangular and T-beam sections is given below.

Rectangular Beam Flexural Reinforcing

Refer to Figure 1. For a rectangular beam, the factored moment, M_u, is resisted by a couple between the concrete in compression and the tension in reinforcing steel. This is expressed in Equation 1.

$$M_u = C_c\left(d_{spandrel} - \frac{a}{2}\right) \qquad \text{Eqn. 1}$$

where $C_c = 0.85\phi_b f'_c a t_s$ and $d_{spandrel}$ is equal to h_s - $d_{r\text{-}bot}$ for positive bending and h_s - $d_{r\text{-}top}$ for negative bending.

Equation 1 can be solved for the depth of the compression block, a, yielding Equation 2.

$$a = d_{spandrel} - \sqrt{d^2_{spandrel} - \frac{2M_u}{0.85 f'_c\ \phi_b\ t_s}} \qquad \text{Eqn. 2}$$

The program uses Equation 2 to determine the depth of the compression block, a.

The depth of the compression block, a, is compared with $0.75\beta_1 c_b$, where

$$\beta_1 = 0.85 - \frac{0.05\left(f'_c - 4{,}000\right)}{1{,}000} \qquad \text{Eqn. 3}$$

with a maximum of 0.85 and a minimum of 0.65. c_b, the distance from the extreme compression fiber to the neutral axis for balanced strain conditions, is given by Equation 4.

$$c_b = \frac{87000}{87000 + f_y} d_{spandrel} \qquad \text{Eqn. 4}$$

Note:

If the required tension reinforcing exceeds 75% of the balanced reinforcing, the program provides compression steel to help resist the applied moment.

Tension Reinforcing Only Required

If $a \le 0.75\beta_1 c_b$, no compression reinforcing is required and the program calculates the area of tension reinforcing using Equation 5.

$$A_s = \frac{M_u}{\phi_b f_y \left(d_{spandrel} - \frac{a}{2} \right)} \qquad \text{Eqn. 5}$$

The steel is placed at the bottom for positive moment and in the top for negative moment.

Note:

The program reports the ratio of top and bottom steel required in the web area. When compression steel is required, these ratios may be large because there is no limit on them. However, the program reports an overstress when the ratio exceeds 4%.

Tension and Compression Reinforcing Required

If $a > 0.75\beta_1 c_b$, compression reinforcing is required and the program calculates required compression and tension reinforcing as follows.

The depth of the concrete compression block, a, is set equal to $a_b = 0.75\beta_1 c_b$. The compressive force developed in the concrete alone is given by Equation 6.

$$C_c = 0.85 f'_c a_b t_s \qquad \text{Eqn. 6}$$

The moment resisted by the couple between the concrete in compression and the tension steel, M_{uc}, is given by Equation 7.

$$M_{uc} = \phi_b C_c \left(d_{spandrel} - \frac{a_b}{2} \right) \qquad \text{Eqn. 7}$$

Therefore, the additional moment to be resisted by the couple between the compression steel and the additional tension steel, M_{us}, is given by

$$M_{us} = M_u - M_{uc} \qquad \text{Eqn. 8}$$

The force carried by the compression steel, C_s, is given by Equation 9.

$$C_s = \frac{M_{us}}{d_{spandrel} - d_r} \qquad \text{Eqn. 9}$$

Referring to Figure 1, the strain in the compression steel, ε'_s, is given by Equation 10.

$$\varepsilon_s^{'} = \frac{0.003\left(c - d_r\right)}{c} \qquad \text{Eqn. 10}$$

The stress in the compression steel, f'_s, is given by Equation 11.

$$f_s^{'} = E_s \varepsilon_s^{'} = \frac{0.003 E_s \left(c - d_r\right)}{c} \qquad \text{Eqn. 11}$$

The term d_r in Equations 9, 10 and 11 is equal to $d_{r\text{-}top}$ for positive bending and equal to $d_{r\text{-}bot}$ for negative bending. In Equations 10 and 11, the term c is equal to a_b/β_1.

The total required area of compression steel, A'_s; is calculated using Equation 12.

$$A_s^{'} = \frac{C_s}{\phi_b (f_s^{'} - 0.85 f_c^{'})} \qquad \text{Eqn. 12}$$

The required area of tension steel for balancing the compression in the concrete web, A_{sw}, is:

$$A_{sw} = \frac{M_{uc}}{\phi_b f_y \left(d_{spandrel} - \frac{a_b}{2}\right)} \qquad \text{Eqn. 13}$$

Note that Equation 13 is similar to Equation 5 that is used when only tension reinforcing is required.

The required area of tension steel for balancing the compression steel, A_{sc}, is:

$$A_{sc} = \frac{M_{us}}{\phi_b f_y \left(d_{spandrel} - d_r\right)} \qquad \text{Eqn. 14}$$

In Equations 13 and 14, $d_{spandrel}$ is equal to h_s - $d_{r\text{-}bot}$ for positive bending and h_s - $d_{r\text{-}top}$ for negative bending. In Equation 14, d_r is equal to $d_{r\text{-}top}$ for positive bending and $d_{r\text{-}bot}$ for negative bending.

The total tension reinforcement A_s is given by Equation 15.

$$A_s = A_{sw} + A_{sc} \quad \text{Eqn. 15}$$

where A_{sw} and A_{sc} are determined from Equations 13 and 14, respectively.

Thus, the total tension reinforcement, A_s, is given by Equation 15 and the total compression reinforcement, A'_s, is given by Equation 12. A_s is to be placed at the bottom of the beam and A'_s at the top for positive bending and vice versa for negative bending.

T-Beam Flexural Reinforcing

T-beam action is only considered effective for positive moment. When designing T-beams for negative moment (i.e., designing top steel), the calculation of required steel is as described in the previous section for rectangular sections. No T-beam data is used in this design. The width of the beam is taken equal to the width of the web.

For positive moment, the depth of the compression block, a, is initially determined using Equation 2. The method for calculating the required reinforcing steel relates the compression block depth, a, calculated using Equation 2, to the depth of the T-beam flange, d_s. See Figure 2.

- **If $a \le d_s$**, the subsequent calculations for the reinforcing steel are exactly the same as previously defined for rectangular section design. However, in that case, the width of the compression block is taken to be equal to the width of the compression flange, b_s. Compression reinforcement is provided when the dimension "a" exceeds $0.75\beta_1 c_b$, where β_1 and c_b are given by Equations 3 and 4, respectively.

- **If $a > d_s$**, the subsequent calculations for the required area of reinforcing steel are performed in two parts. First, the tension steel required to balance the compressive force in the flange is determined, and second, the tension steel required to balance the compressive force in the web is determined. If necessary, compression steel is added to help resist the design moment.

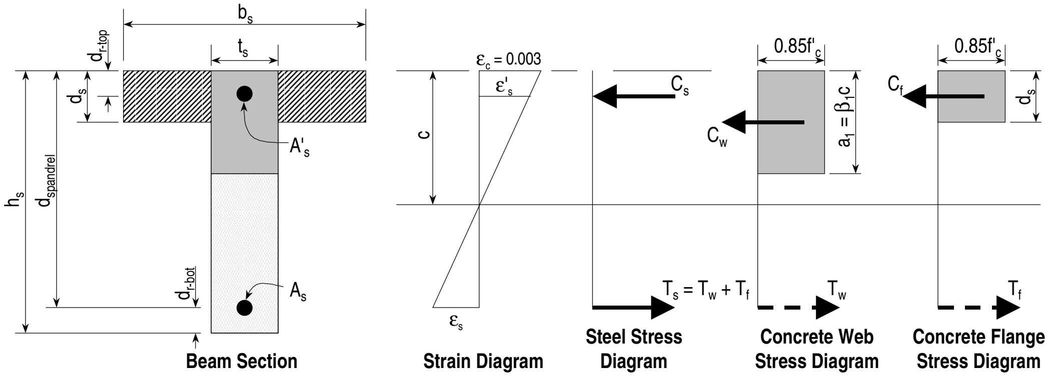


Figure 2: Design of a Wall Spandrel with a T-Beam Section, Positive Moment

The remainder of this section describes in detail the design process used by the program for T-beam spandrels when $a > d_s$.

Refer to Figure 2. The compression force in the protruding portion of the flange, C_f, is given by Equation 16. The protruding portion of the flange is shown cross-hatched.

$$C_f = 0.85f'_c\,(b_s - t_s)d_s \qquad \text{Eqn. 16}$$

Note:

T-beam action is only considered for positive moment.

The required area of tension steel for balancing the compression force in the concrete flange, A_{sf}, is:

$$A_{sf} = \frac{C_f}{f_y} \qquad \text{Eqn. 17}$$

The portion of the total moment, M_u, that is resisted by the flange, M_{uf}, is given by Equation 18.

$$M_{uf} = \phi_b C_f \left(d_{spandrel} - \frac{d_s}{2} \right) \qquad \text{Eqn. 18}$$

Therefore the balance of the moment to be carried by the web, M_{uw}, is given by

$$M_{uw} = M_u - M_{uf} \qquad \text{Eqn. 19}$$

The web is a rectangular section of width t_s and depth h_s for which the design depth of the compression block, a_1, is recalculated as:

$$a_1 = d_{spandrel} - \sqrt{d_{spandrel}^2 - \frac{2M_{uw}}{0.85f'_c\,\phi_b\,t_s}} \qquad \text{Eqn. 20}$$

Tension Reinforcing Only Required

If $a_1 \le 0.75\beta_1 c_b$, where β_1 and c_b are calculated from Equations 3 and 4, respectively, no compression reinforcing is required and the program calculates the area of tension steel for balancing the compression force in the concrete web, A_{sw}, using Equation 21.

$$A_{sw} = \frac{M_{uw}}{\phi_b f_y\left(d_{spandrel} - \frac{a_1}{2}\right)} \qquad \text{Eqn. 21}$$

The total tension reinforcement A_s is given by Equation 22.

$$A_s = A_{sf} + A_{sw} \qquad \text{Eqn. 22}$$

The total tension reinforcement, A_s, given by Equation 22 is to be placed at the bottom of the beam for positive bending.

Tension and Compression Reinforcing Required

If $a_1 > 0.75\beta_1 c_b$, where a_1 is calculated using Equation 20 and β_1 and c_b are calculated from Equations 3 and 4, respectively, compression reinforcing is required. In that case, the required reinforcing is computed as follows.

The depth of the concrete compression block, a, is set equal to $a_b = 0.75\beta_1 c_b$. The compressive force developed in the web concrete alone is given by Equation 23.

$$C_w = 0.85f'_c a_b t_s \qquad \text{Eqn. 23}$$

The moment resisted by the couple between the concrete web in compression and the tension steel, M_{uc}, is given by Equation 24.

$$M_{uc} = \phi_b C_w \left(d_{spandrel} - \frac{a_b}{2} \right) \quad \text{Eqn. 24}$$

Therefore, the additional moment to be resisted by the couple between the compression steel and the tension steel, M_{us}, is given by:

$$M_{us} = M_{uw} - M_{uc} \quad \text{Eqn. 25}$$

Referring to Figure 2, the force carried by the compression steel, C_s, is given by Equation 26.

$$C_s = \frac{M_{us}}{d_{spandrel} - d_{r\text{-}top}} \quad \text{Eqn. 26}$$

The strain in the compression steel, ε'_s, is given by Equation 27.

$$\varepsilon'_s = \frac{0.003\left(c - d_{r\text{-}top}\right)}{c} \quad \text{Eqn. 27}$$

The stress in the compression steel, f'_s, is given by Equation 28.

$$f'_s = E_s \varepsilon'_s = \frac{0.003 E_s \left(c - d_{r\text{-}top}\right)}{c} \quad \text{Eqn. 28}$$

In Equations 27 and 28 the term c is equal to a_b/β_1.

The required area of compression steel, A'_s; is calculated using Equation 29.

$$A'_s = \frac{C_s}{\phi_b f'_s} \quad \text{Eqn. 29}$$

The required area of tension steel for balancing the compression in the concrete web, A_{sw}, is:

$$A_{sw} = \frac{M_{uc}}{\phi_b f_y \left(d_{spandrel} - \frac{a_b}{2} \right)} \quad \text{Eqn. 30}$$

The required area of tension steel for balancing the compression steel, A_{sc}, is:

$$A_{sc} = \frac{M_{us}}{\phi_b f_y \left(d_{spandrel} - d_{r\text{-}top}\right)} \quad \text{Eqn. 31}$$

The total tension reinforcement A_s is given by Equation 15.

$$A_s = A_{sf} + A_{sw} + A_{sc} \quad \text{Eqn. 32}$$

where A_{sf}, A_{sw} and A_{sc} are determined from Equations 17, 30 and 31, respectively.

The total tension reinforcement, A_s, is given by Equation 32 and the total compression reinforcement, A'_s, is given by Equation 29. A_s is to be placed at the bottom of the beam and A'_s at the top of the beam.

Technical Note 17
Spandrel Shear Design

This Technical Note describes how the program designs concrete wall spandrels for shear using the 1997 UBC. Note that in this program you cannot specify shear reinforcing and then have the program check it. The program only designs the spandrel for shear and reports how much shear reinforcing is required.

The program allows consideration of rectangular sections and T-beam sections for wall spandrels. The shear design for both of these types of spandrel sections is identical.

General

The wall spandrel shear reinforcing is designed for each of the design load combinations. The required area of reinforcing for vertical shear is only calculated at the ends of the spandrel beam.

In this program, wall spandrels are designed for major direction flexure and shear forces only. Effects caused by any axial forces, minor direction bending, torsion or minor direction shear that may exist in the spandrels must be investigated by the user independent of the program.

The following steps are involved in designing the shear reinforcing for a particular wall spandrel section for a particular design loading combination at a particular station.

1. Determine the factored shear force V_u.
2. Determine the shear force, V_c, that can be carried by the concrete.
3. Determine the required shear reinforcing to carry the balance of the shear force.

Note:

You can specify in the overwrites that V_c is to be ignored (set to zero) for spandrel shear calculations.

Step 1 needs no further explanation. The following two sections describe in detail the algorithms associated with Steps 2 and 3.

Determine the Concrete Shear Capacity

The shear force carried by the concrete, V_c, is calculated using Equation 1.

$$V_c = 2R_{LW}\sqrt{f'_c}\ t_s d_{spandrel} \qquad \text{Eqn. 1}$$

Equation 1 is based on Equation 11-3 in Chapter 21, Section 1911.3.1.1 of the 1997 UBC.

Note that there is an overwrite available that allows you to ignore the concrete contribution to the shear strength of the spandrel. If this overwrite is activated, the program sets V_c to zero for the spandrel.

The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this Technical Note is a shear strength reduction factor that applies to lightweight concrete. It is equal to 1 for normal weight concrete. This factor is specified in the concrete material properties.

Note:

The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this Technical Note is a shear strength reduction factor that applies to lightweight concrete. It is equal to 1 for normal weight concrete. This factor is specified in the concrete material properties.

Determine the Required Shear Reinforcing

One of the terms used in calculating the spandrel shear reinforcing is $d_{spandrel}$, which is the distance from the extreme compression fiber to the centroid of the tension steel. For shear design, the program takes $d_{spandrel}$ to be equal to the smaller of h_s-$d_{r\text{-}top}$ and h_s-$d_{r\text{-}bot}$.

Seismic and Nonseismic Spandrels

In this entire subsection the term ϕ is equal to ϕ_{vns} for nonseismic spandrels and to ϕ_{vs} for seismic spandrels.

Given V_u and V_c, the required force to be carried by the shear reinforcing, V_s, is calculated using Equation 2.

$$V_s = V_n - V_c = \frac{V_u}{\phi} - V_c \qquad \text{Eqn. 2}$$

If V_s as calculated in Equation 2 exceeds $8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}$, a failure condition is reported per UBC Section 1911.5.6.8.

Given V_s, Equation 3 initially calculates the required vertical shear reinforcing in area per unit length (e.g., square inches per foot) for both seismic and nonseismic wall spandrels (as indicated in the preferences). Note that additional requirements that are checked for both seismic and nonseismic wall spandrels are given following Equation 3.

$$A_v = \frac{V_n - V_c}{f_{ys} d_{spandrel}} = \frac{V_s}{f_{ys} d_{spandrel}} \qquad \text{Eqn. 3}$$

Note:

You can set the output units for the distributed shear reinforcing in the shear wall design preferences.

The following additional checks are also performed for both seismic and nonseismic spandrels.

- When $\frac{L_s}{d_{spandrel}} > 5$, the program verifies:

$$V_s \le 8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}, \qquad \text{Eqn. 4a}$$

  otherwise a failure condition is declared per Section 1911.5.6.8 of the 1997 UBC.

✓ When $\frac{L_s}{d_{spandrel}} > 5$ and $\frac{V_u}{\phi} > 0.5V_c$, the minimum areas of vertical and horizontal shear reinforcing in the spandrel are:

$$A_{v\text{-}min} = \frac{50t_s}{f_{ys}} \qquad \text{Eqn. 4b}$$

$$A_{h\text{-}min} = 0 \qquad \text{Eqn. 4c}$$

Equation 4b is based on Equation 11-13 in Section 1911.5.5.3 of the 1997 UBC.

✓ When $\frac{L_s}{d_{spandrel}} > 5$ and $\frac{V_u}{\phi} \le 0.5V_c$, the minimum areas of vertical and horizontal shear reinforcing in the spandrel are:

$$A_{v\text{-}min} = A_{h\text{-}min} = 0 \qquad \text{Eqn. 4d}$$

Note:

When calculating the $L_s / d_{spandrel}$ term, the program always uses the smallest value of $d_{spandrel}$ that is applicable to the spandrel.

- When $2 \le \frac{L_s}{d_{spandrel}} \le 5$, the program verifies:

$$V_n = \frac{V_u}{\phi} \le \frac{2}{3}\left(10 + \frac{L_s}{d_{spandrel}}\right) R_{LW}\sqrt{f'_c}\, t_s d_{spandrel} \qquad \text{Eqn. 4e}$$

otherwise a failure condition is declared per Equation 11-27 in Section 1911.8.4 of the 1997 UBC. For this condition, the minimum areas of horizontal and vertical shear reinforcing in the spandrel are:

$$A_{v\text{-}min} = 0.0015t_s \qquad \text{Eqn. 4f}$$

$$A_{h\text{-}min} = 0.0025t_s \qquad \text{Eqn. 4g}$$

- When $\frac{L_s}{d_{spandrel}} < 2$, the program verifies:

$$V_n = \frac{V_u}{\phi} \le 8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}\,, \qquad \text{Eqn. 4h}$$

otherwise a failure condition is declared per Section 1911.8.4 of the 1997 UBC. For this condition, the minimum areas of horizontal and vertical shear reinforcing in the spandrel are:

$$A_{v\text{-}min} = 0.0015t_s \qquad \text{Eqn. 4i}$$

$$A_{h\text{-}min} = 0.0025t_s \qquad \text{Eqn. 4j}$$

Equations 4f and 4i are based on Section 1911.8.9 of the 1997 UBC. Equations 4g and 4j are based on Section 1911.8.10 of the 1997 UBC.

Note that the check in Equation 4a is based on V_s, whereas the checks in Equations 4e and 4h are based on V_n.

Note:

For nonseismic spandrels, A_{vd} is reported as zero.

Seismic Spandrels Only

For seismic spandrels only, in addition to the requirements of the previous subsection, an area of diagonal shear reinforcement in coupling beams is also calculated when $\frac{L_s}{d_{spandrel}} < 4$ using Equation 5.

$$A_{vd} = \frac{V_u}{2\,(0.85)\,f_{ys}\sin\alpha}\,, \qquad \text{Eqn. 5}$$

where,

$$\sin\alpha = \frac{0.8h_s}{\sqrt{L_s^2 + (0.8h_s)^2}}\,,$$

where h_s is the height of the spandrel and L_s is the length of the spandrel.

In the output, the program reports the diagonal shear reinforcing as either required or not required (i.e., optional). The diagonal shear reinforcing is reported as required when Vu > 4 $\sqrt{f'_c}$ $bd_{spandrel}$.

Technical Note 18
Wall Pier Boundary Elements

This Technical Note describes how the program considers the boundary element requirements for each leg of concrete wall piers using the 1997 UBC. The program uses an approach based on the requirements of Section 1921.6.6.4 in the 1997 UBC.

Note that the boundary element requirements are considered separately for each design load case that includes seismic load.

Note:

The program considers only the requirements of section 1921.6.6.4 of the 1997 UBC in determining boundary element requirements. Section 1921.6.6.5 is not considered by the program.

Details of Check for Boundary Element Requirements

The following information is available for the boundary element check:

- The design forces P_u, V_u and M_u for the pier section.
- The length of the wall pier, L_p, the gross area of the pier, A_g, and the net area of the pier, A_{cv}. The net area of the pier is the area bounded by the web thickness, t_p, and the length of the pier. Refer to Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Sections for an illustration of the dimensions L_p and t_p.
- The area of steel in the pier, A_s. This area of steel is either calculated by the program or it is provided by the user.
- The material properties of the pier, f'_c and f_y.
- The symmetry of the wall pier (i.e., is the left side of the pier the same as the right side of the pier). Only the geometry of the pier is considered, not the reinforcing, when determining if the pier is symmetrical. Figure 1 shows some examples of symmetrical and unsymmetrical wall piers. Note

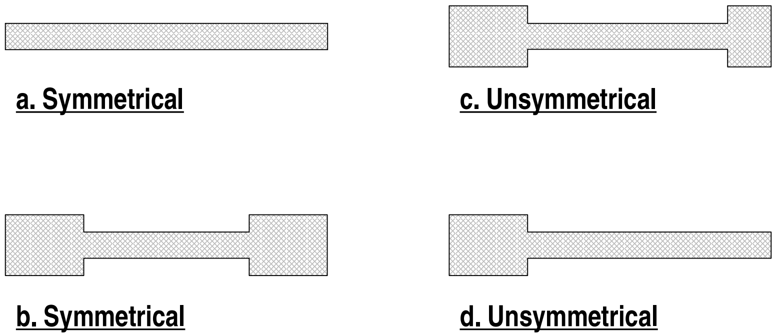


Figure 1 Example Plan Views of Symmetrical and Unsymmetrical Wall Piers

that a pier defined in Section Designer is assumed to be unsymmetrical unless it is made up of a single rectangular shape.

Using this information, the program calculates the value of P_O, which is the nominal axial load strength of the wall using Equation 1.

$$P_O = 0.85f'_c \,(A_g - A_s) + f_y A_s \qquad \text{Eqn. 1}$$

Note:

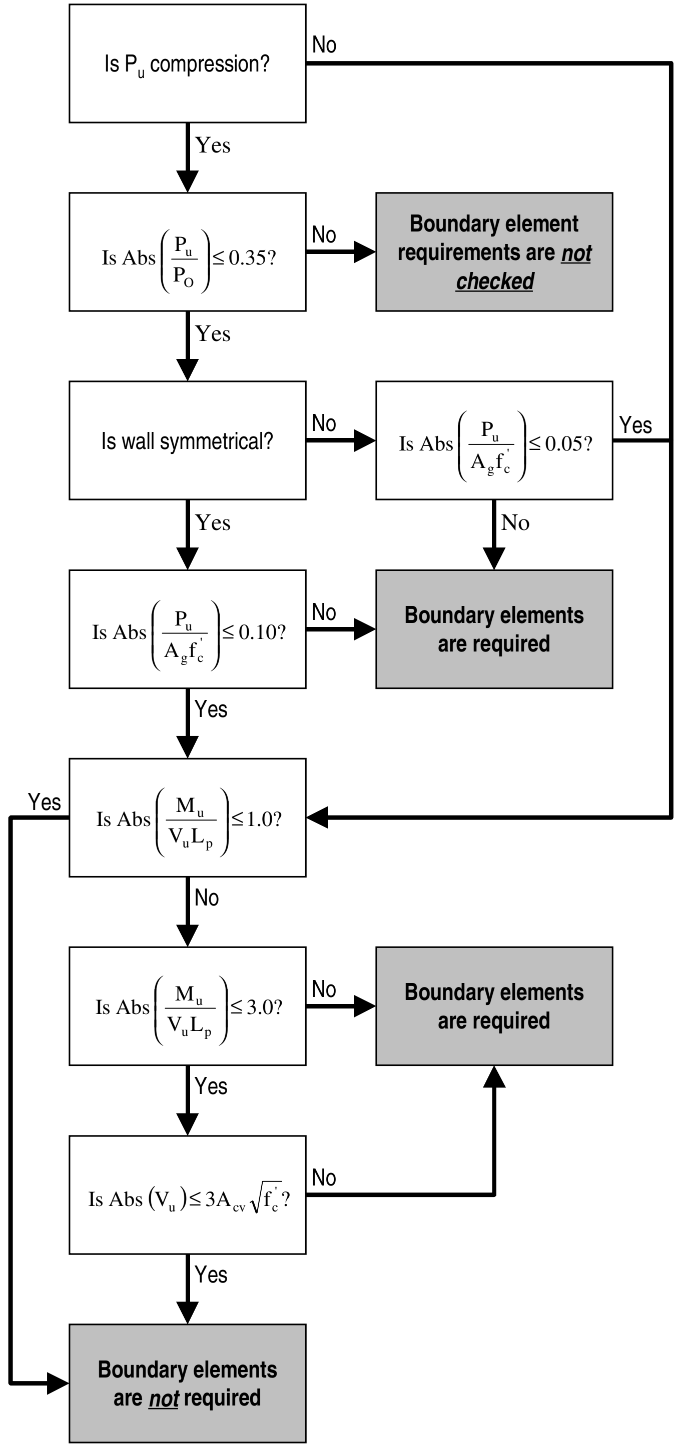
For simplified design only, if there is a flexural failure in any design load combination, the program sets A_s in Equation 1 to zero for all design load combinations considered for the pier.

After the value of P_O is known, the program calculates four quantities that are used to determine the boundary zone requirements. These quantities are:

- $\dfrac{P_u}{P_O}$
- $\dfrac{M_u}{V_u L_p}$
- $\dfrac{P_u}{A_g f'_c}$
- $3A_{cv}\sqrt{f'_c}$

The flowchart in Figure 2 illustrates the process the program uses to determine if boundary elements are required. Note that if P_u exceeds 0.35 P_O, the boundary element requirements are not checked. This is based on 1997 UBC Section 1921.6.6.3.

Figure 2
Flowchart of the Process the Program Uses to Determine if Boundary Elements Are Required



If boundary elements are required, the program calculates the minimum required length of the boundary zone at each end of the wall, L_{BZ}, according to the requirements of Section 1921.6.6.4 in the 1997 UBC. The UBC requires that L_{BZ} vary linearly from $0.25L_p$ to $0.15L_p$ for P_u, varying from $0.35P_O$ to $0.15P_O$, and that L_{BZ} shall not be less than $0.15L_p$. Based on these requirements, the program calculates L_{BZ} using either Equation 2a or 2b, depending on whether P_u is compression or tension.

When P_u is compression:

$$L_{BZ} = \left[\text{Abs}\left(\frac{P_u}{2P_O}\right) + 0.075\right] L_p \geq 0.15L_p \qquad \text{Eqn. 2a}$$

When P_u is tension:

$$L_{BZ} = 0.15L_p \qquad \text{Eqn. 2b}$$

Figure 3 illustrates the boundary zone length L_{BZ}.

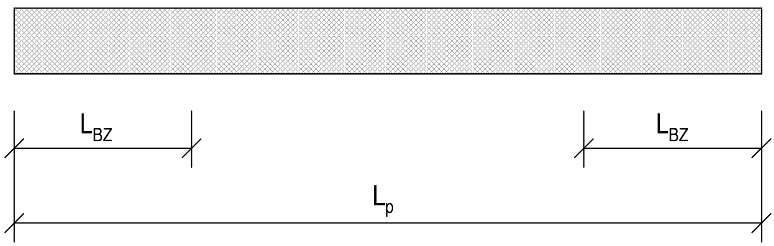


Figure 3: Illustration of Boundary Zone Length, L_{BZ}

Example

Figure 4 shows an example wall pier. The pier is 12.5 feet long. It is reinforced with #5 bars at 12 inches on center on each face. Refer to the figure for properties and forces.

Note:

Boundary element requirements are considered by the program for two- and three-dimensional wall piers

The calculations follow:

P_u = 1,000 kips (given)

L_p = 12.5 feet = 150 inches (given)

A_g = 12.5 ft * 1 ft = 12.5 ft^2 = 1,800 in^2

A_s = 13 bars * 2 faces * 0.31 in^2 = 8.06 in^2

f'_c = 4 ksi (given)

f_y = 60 ksi (given)

The pier is symmetrical. (given)

$P_O = 0.85f'_c\,(A_g - A_s) + f_yA_s$

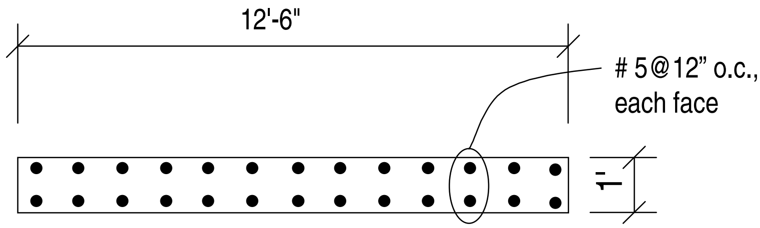
P_O = 0.85 * 4 (1,800 - 8.06) + 60 * 8.06 = 6,576 kips

$$\frac{P_u}{P_O} = \frac{1{,}000}{6{,}576} = 0.152 < 0.35 \quad \underline{\textbf{OK}}$$

$$\frac{P_u}{A_g f'_c} = \frac{1{,}000}{1{,}800 * 4} = 0.139 > 0.1 \quad \underline{\textbf{NG}}$$

Therefore boundary elements are required.

$$L_{BZ} = \left(\frac{1{,}000}{2 * 6{,}576} + 0.075\right) * 150 = 22.7 \text{ inches}$$



f'c = 4 ksi
fy = 60 ksi

P_u = 1000 kips
V_u = 350 kips
M_u = 3500 kips

Figure 4: Wall Pier Example Calculations

Displaying the pier boundary zone data provides either the required boundary zone length, or "NC" (short for Not Checked) if boundary zone requirements are not checked because P_u/P_o > 0.35, or "NN" (short for Not Needed) if boundary zones are not required.

SHEAR WALL DESIGN UBC 97

Technical Note 19

Input Data

General

This Technical Note describes the shear wall input data that can be printed to a printer or to a text file when you click the **File menu > Print Tables > Shear Wall Design** command.

Using the Print Shear Wall Design Tables Form

To print Shear Wall design input data directly to a printer, use the **File menu > Print Tables > Shear Wall Design** command and click the check box on the Print Shear Wall Design Tables form next to the desired type(s) of data. Click the **OK** button to send the print to your printer. Click the **Cancel** button rather than the **OK** button to cancel the print.

Use the **File menu > Print Setup** command and the **Setup>>** button to change printers, if necessary.

To print shear wall design input data to a file, use the **File menu > Print Tables > Shear Wall Design** command and click the Print to File check box on the Print Shear Wall Design Tables form. Click the **Filename>>** button to change the path or filename. Use the appropriate file extension for the desired format (e.g., .txt, .xls, .doc). Click the **OK** buttons on the Open File for Printing Tables form and the Print Shear Wall Design Tables form to complete the request.

Note:

The **File menu > Display Input/Output Text Files** command is useful for displaying output that is printed to a text file.

The Append check box allows you to add data to an existing file. The path and filename of the current file is displayed in the box near the bottom of the Print Shear Wall Design Tables form. Data will be added to this file. Or use the

Filename>> button to locate another file, and when the Open File for Printing Tables caution box appears, click Yes to replace the existing file.

If you select a specific shear wall(s) before using the **File menu > Print Tables > Shear Wall Design** command, the Selection Only check box will be checked. The print will be for the selected wall(s) only. If you uncheck the Selection Only check box, the print will be for all shear walls.

Summary Input Data

Summary input data are described in Shear Wall Design Technical Note 4 Input Data.

Design Preferences Input Data

The output for the Shear Wall design preferences is provided in a series of tables. The tables correspond to the tabs in the Preferences form. You can click the **Options menu > Preferences > Shear Wall Design** command to access the Shear Wall preferences.

Note:

The Shear Wall preferences are described in UBC97 Shear Wall Design Technical Note 11 Preferences.

Recall that the Shear Wall preferences apply to all beams designed using the Shear Wall Design postprocessor. A few of the preference items can be overwritten on a beam-by-beam basis in the Shear Wall overwrites. Those preferences items that can be overwritten are mentioned in this documentation. You can select one or more beams and then click the **Design menu > Shear Wall Design > View/Revise Overwrites** command to access the Shear Wall overwrites.

Summary input data are described in Shear Wall Design Technical Note 4 Input Data.

Table 1 of Shear Wall Design Technical Note 4 Input Data identifies the Shear Wall Design Preferences Output.

SHEAR WALL DESIGN UBC97

Technical Note 20
Output Details

This program provides output details that can be printed to a printer or to a text file. The program presents the data in tabular form with column headings. This Technical Note identifies each of the column headings for the pier and spandrel detailed output data and provides a description of what is included in the column. The six types of detailed output available are:

- Simplified pier section design (Table 1).
- Uniform Reinforcing pier section design (Table 2).
- General Reinforcing pier section design (Table 2).
- Uniform Reinforcing pier section check (Table 3).
- General Reinforcing pier section check (Table 3).
- Spandrel design (Table 4).

Each of these types of output is described in the tables provided in Shear Wall Design Technical Note 5 Output Data.

Technical Note 21
General and Notation

Introduction to the ACI318-99 Series of Technical Notes

The Shear Wall Design ACI318-99 series of Technical Notes describes the details of the structural steel design and stress check algorithms used by the program when the user selects the ACI318-99 design code. The various notations used in this series are described herein.

The design is based on loading combinations specified by the user. To facilitate the design process, the program provides a set of default load combinations that should satisfy requirements for the design of most building type structures. See Shear Wall Design ACI318-99 Technical Note 25 Design Load Combinations for more information.

The program also performs the following design, check, or analysis procedures in accordance with ACI318-99 requirements:

- Design and check of concrete wall piers for flexural and axial loads; see Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.
- Design of concrete wall piers for shear; see Shear Wall Design ACI318-99 Technical Note 27 Wall Pier Shear Design.
- Design of concrete shear wall spandrels for flexure; see Shear Wall Design ACI318-99 Technical Note 28 Spandrel Flexural Design.
- Design of concrete wall spandrels for shear; see Shear Wall Design ACI318-99 Technical Note 29 Spandrel Shear Design.
- Consideration of the boundary element requirements for concrete wall piers using an approach based on the requirements of Section 21.6.6 in the ACI318-99; see Shear Wall Design ACI318-99 Technical Note 30 Wall Pier Boundary Elements.

The program provides detailed output data for Simplified pier section design, Section Designer pier section *design,* Section Designer pier section *check,* and Spandrel design. See Shear Wall Design ACI318-99 Technical Note 32 Output Details.

English as well as SI and MKS metric units can be used for input. The program code is based on Kip-Inch-Second units. For simplicity, all equations and descriptions presented in this series of Technical Notes corresponds to **pound-inch-second** units unless otherwise noted.

Notation

Following is the notation used in the Shear Wall Design ACI318-99 series of Technical Notes.

A_{cv} Net area of a wall pier bounded by the length of the wall pier, L_p, and the web thickness, t_p, inches^2.

A_g Gross area of a wall pier, inches^2.

$A_{h\text{-}min}$ Minimum required area of distributed horizontal reinforcing steel required for shear in a wall spandrel, inches^2 / in.

A_s Area of reinforcing steel, inches^2.

A_{sc} Area of reinforcing steel required for compression in a pier edge member, or the required area of tension steel required to balance the compression steel force in a wall spandrel, inches^2.

$A_{sc\text{-}max}$ Maximum area of compression reinforcing steel in a wall pier edge member, inches^2.

A_{sf} The required area of tension reinforcing steel for balancing the concrete compression force in the extruding portion of the concrete flange of a T-beam, inches^2.

A_{st} Area of reinforcing steel required for tension in a pier edge member, inches^2.

$A_{st\text{-}max}$	Maximum area of tension reinforcing steel in a wall pier edge member, inches^2.
A_v	Area of reinforcing steel required for shear, inches^2 / in.
A_{vd}	Area of diagonal shear reinforcement in a coupling beam, inches^2.
$A_{v\text{-}min}$	Minimum required area of distributed vertical reinforcing steel required for shear in a wall spandrel, inches^2 / in.
A_{sw}	The required area of tension reinforcing steel for balancing the concrete compression force in a rectangular concrete beam, or for balancing the concrete compression force in the concrete web of a T-beam, inches^2.
A'_s	Area of compression reinforcing steel in a spandrel, inches^2.
B_1, B_2...	Length of a concrete edge member in a wall with uniform thickness, inches.
C_a	Seismic coefficient provided in UBC Chapter 16, Table 16-Q, unitless.
C_c	Concrete compression force in a wall pier or spandrel, pounds.
C_f	Concrete compression force in the extruding portion of a T-beam flange, pounds.
C_s	Compression force in wall pier or spandrel reinforcing steel, pounds.
C_w	Concrete compression force in the web of a T-beam, pounds.
D/C	Demand/Capacity ratio as measured on an interaction curve for a wall pier, unitless.

DB1 Length of a user-defined wall pier edge member, inches. This can be different on the left and right sides of the pier, and it also can be different at the top and the bottom of the pier. See Figure 1 of Shear Wall Design Technical Note 6 Wall Pier Design Sections.

DB2 Width of a user-defined wall pier edge member, inches. This can be different on the left and right sides of the pier, and it also can be different at the top and the bottom of the pier. See Figure 1 of Shear Wall Design Technical Note 6 Wall Pier Design Sections.

E The earthquake load on a structure resulting from the combination of the horizontal component, E_h, and the vertical component, E_v.

E_h The horizontal component of earthquake load.

E_s Modulus of elasticity of reinforcing steel, psi.

E_v The vertical component of earthquake load.

I Importance factor provided in UBC Chapter 16, Table 16-K, unitless.

IP-max The maximum ratio of reinforcing considered in the design of a pier with a Section Designer section, unitless.

IP-min The minimum ratio of reinforcing considered in the design of a pier with a Section Designer section, unitless.

L_{BZ} Horizontal length of the boundary zone at each end of a wall pier, inches.

L_p Horizontal length of wall pier, inches. This can be different at the top and the bottom of the pier.

L_s Horizontal length of wall spandrel, inches.

LL Live load

M_n Nominal bending strength, pound-inches.

M_u Factored bending moment at a design section, pound-inches.

M_{uc} In a wall spandrel with compression reinforcing, the factored bending moment at a design section resisted by the couple between the concrete in compression and the tension steel, pound-inches.

M_{uf} In a wall spandrel with a T-beam section and compression reinforcing, the factored bending moment at a design section resisted by the couple between the concrete in compression in the extruding portion of the flange and the tension steel, pound-inches.

M_{us} In a wall spandrel with compression reinforcing, the factored bending moment at a design section resisted by the couple between the compression steel and the tension steel, pound-inches.

M_{uw} In a wall spandrel with a T-beam section and compression reinforcing, the factored bending moment at a design section resisted by the couple between the concrete in compression in the web and the tension steel, pound-inches.

OC On a wall pier interaction curve the "distance" from the origin to the capacity associated with the point considered.

OL On a wall pier interaction curve the "distance" from the origin to the point considered.

P_b The axial force in a wall pier at a balanced strain condition, pounds.

P_{left} Equivalent axial force in the left edge member of a wall pier used for design, pounds. This may be different at the top and the bottom of the wall pier.

P_{max} Limit on the maximum compressive design strength specified by ACI318-99, pounds.

Pmax Factor Factor used to reduce the allowable maximum compressive design strength, unitless. The ACI318-99 specifies this factor to be 0.80. This factor can be revised in the preferences.

P_n Nominal axial strength, pounds.

P_O Nominal axial load strength of a wall pier, pounds.

P_{oc} The maximum compression force a wall pier can carry with strength reduction factors set equal to one, pounds.

P_{ot} The maximum tension force a wall pier can carry with strength reduction factors set equal to one, pounds.

P_{right} Equivalent axial force in the right edge member of a wall pier used for design, pounds. This may be different at the top and the bottom of the wall pier.

P_u Factored axial force at a design section, pounds.

PC_{max} Maximum ratio of compression steel in an edge member of a wall pier, unitless.

PT_{max} Maximum ratio of tension steel in an edge member of a wall pier, unitless.

R_{LW} Shear strength reduction factor as specified in the concrete material properties, unitless. This reduction factor applies to light-weight concrete. It is equal to 1 for normal weight concrete.

RLL Reduced live load.

T_s Tension force in wall pier reinforcing steel, pounds.

V_c The portion of the shear force carried by the concrete, pounds.

V_n Nominal shear strength, pounds.

V_s The portion of the shear force in a spandrel carried by the shear reinforcing steel, pounds.

V_u Factored shear force at a design section, pounds.

WL Wind load.

a Depth of the wall pier or spandrel compression block, inches.

a_b Depth of the compression block in a wall spandrel for balanced strain conditions, inches.

a_1 Depth of the compression block in the web of a T-beam, inches.

b_s Width of the compression flange in a T-beam, inches. This can be different on the left and right end of the T-beam.

c Distance from the extreme compression fiber of the wall pier or spandrel to the neutral axis, inches.

c_b Distance from the extreme compression fiber of a spandrel to the neutral axis for balanced strain conditions, inches.

$d_{r\text{-}bot}$ Distance from bottom of spandrel beam to centroid of the bottom reinforcing steel, inches. This can be different on the left and right ends of the beam.

$d_{r\text{-}top}$ Distance from top of spandrel beam to centroid of the top reinforcing steel, inches. This can be different on the left and right ends of the beam.

d_s Depth of the compression flange in a T-beam, inches. This can be different on the left and right ends of the T-beam.

$d_{spandrel}$ Depth of spandrel beam minus cover to centroid of reinforcing, inches.

f_y Yield strength of steel reinforcing, psi. This value is used for flexural and axial design calculations.

f_{ys} Yield strength of steel reinforcing, psi. This value is used for shear design calculations.

f'_c Concrete compressive strength, psi. This value is used for flexural and axial design calculations.

f'_{cs} Concrete compressive strength, psi. This value is used for shear design calculations.

f'_s Stress in compression steel of a wall spandrel, psi.

h_s Height of a wall spandrel, inches. This can be different on the left and right ends of the spandrel.

p_{max} Maximum ratio of reinforcing steel in a wall pier with a Section Designer section that is designed (not checked), unitless.

p_{min} Minimum ratio of reinforcing steel in a wall pier with a Section Designer section that is designed (not checked), unitless.

t_p Thickness of a wall pier, inches. This can be different at the top and bottom of the pier.

t_s Thickness of a wall spandrel, inches. This can be different on the left and right ends of the spandrel.

ΣDL The sum of all dead load cases.

ΣLL The sum of all live load cases.

ΣRLL The sum of all reduced live load cases.

α The angle between the diagonal reinforcing and the longitudinal axis of a coupling beam.

β_1 Unitless factor defined in Section 10.2.7.3 of ACI318-99.

ε Reinforcing steel strain, unitless.

ε_s Reinforcing steel strain in a wall pier, unitless.

ε'_s Compression steel strain in a wall spandrel, unitless.

ϕ Strength reduction factor, unitless.

ϕ_b Strength reduction factor for bending, unitless. The default value is 0.9.

ϕ_c Strength reduction factor for bending plus high axial compression in a concrete pier, unitless. The default value is 0.7.

ϕ_{vns} Strength reduction factor for shear in a nonseismic pier or spandrel, unitless. The default value is 0.85.

ϕ_{vs} Strength reduction factor for shear in a seismic pier or spandrel, unitless. The default value is 0.6.

ρ Reliability/redundancy factor specified in Section 1630.1.1 of the 1997 UBC, unitless.

σ_s Reinforcing steel stress in a wall pier, psi.

Technical Note 22
Interactive Design Output

Overview

This Technical Note describes how to use interactive shear wall design and review and provides a description of the output obtained when the ACI318-99 code is selected. Interactive design is a powerful mode that allows quick, on-screen review of design results for a specific pier or spandrel. This mode allows easy modification to design parameters (overwrites) and immediate review of the new results.

Note that a design must have been run for the interactive design mode to be available. To run a design, click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.

To enter the interactive design and review mode, right click on a wall pier or spandrel *while the design results are displayed*. If design results are not currently displayed (and the design has been run), click the **Design menu > Shear Wall Design > Interactive Wall Design** command and then right click a pier or spandrel to enter the interactive design and review mode for that pier or spandrel.

Note that if both a pier and a spandrel label are assigned to the right-clicked object, a pop-up box offers the choice to enter the interactive design and review mode for the pier or for the spandrel.

It may be helpful to read this Technical Note and the following notes to fully understand the output described:

Shear Wall Design Technical Note 1 General Design Information

Shear Wall Design Technical Note 6 Wall Pier Design Sections

Shear Wall Design Technical Note 7 Wall Spandrel Design Sections

Shear Wall Design ACI318-99 Technical Note 23 Preferences

Shear Wall Design ACI318-99 Technical Note 24 Overwrites

Shear Wall Design ACI318-99 Technical Note 25 Design Load Combinations

Shear Wall Design ACI318-99 Technical Note 30 Wall Pier Boundary Elements

Interactive Pier Design and Review

When you right click on a pier for interactive design, the Pier Design form will display. This form provides general information at the top of the box that identifies and locates the pier. Additionally, the form displays output information for flexural design, shear design and the boundary element check.

The look of the interactive pier design and review form is different depending on which of the five types of design you do. The five choices are:

- Design of a pier specified as a Simplified section
- Design of a pier specified as a Uniform Reinforcing section
- Design of a pier specified as a General Reinforcing section
- Check of a pier specified as a Uniform Reinforcing section
- Check of a pier specified as a General Reinforcing section

The output associated with each of these five choices is described in the next three sections.

Design of a Simplified Section

Right clicking on a simplified pier section for interactive design displays the Pier Design form. General information that identifies and locates the pier is displayed at the top of this form. Output information for flexural design, shear design and the boundary element check is also displayed. Several command buttons are on the form. A description of the command buttons is provided at the end of this Technical Note. Table 1 identifies the Data Name and provides a brief Data Description.

Table 1 Output Data for Design of a Simplified Section

DATA NAME	DATA DESCRIPTION
General Identification Data	
Story ID	The story level associated with the pier.
Pier ID	The label assigned to the pier.
X Loc	The global X-coordinate of the plan location of the centroid of the *bottom* of the pier.
Y Loc	The global Y-coordinate of the plan location of the centroid of the *bottom* of the pier.
Flexural Design Data The flexural design data is reported separately for tension design and for compression design. Check the steel area required for both tension and compression design and use the maximum for your pier.	
RLLF	A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.
Tension Design	
Station Location	This is Left Top, Right Top, Left Bottom or Right Bottom and designates the location of the reported reinforcing steel.
Edge Length	Length of the program-determined edge member or length of the user-specified edge member (i.e., DB1). Note that the design algorithm is set up such that the edge length used is always the same for tension design and for compression design.
Tension Rebar	Maximum area of reinforcing steel required to resist tension. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Tension Combo	The design load combination associated with the required tension rebar.
Pu	The factored design axial load associated with the Tension Combo.
Mu	The factored design moment associated with the Tension Combo.

Table 1 Output Data for Design of a Simplified Section

DATA NAME	DATA DESCRIPTION
Compression Design	
Station Location	This is Left Top, Right Top, Left Bottom or Right Bottom and designates the location of the reported reinforcing steel.
Edge Length	Length of the program-determined edge member or length of the user-specified edge member (i.e., DB1). Note that the design algorithm is set up such that the edge length used is always the same for tension design and for compression design.
Compression Rebar	Maximum area of reinforcing steel required to resist compression. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Compression Combo	The design load combination associated with the required compression rebar.
Pu	The factored design axial load associated with the Compression Combo.
Mu	The factored design moment associated with the Compression Combo.
Shear Design Data	
EQF	A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See EQ Factor in Shear Wall Design ACI318-99 Technical Note 24 Overwrites for more information.
Station Location	This is either Top or Bot and designates the location (top or bottom) of the reported shear reinforcing steel.
Rebar	Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Shear Combo	The design load combination associated with the specified shear reinforcing.

Table 1 Output Data for Design of a Simplified Section

DATA NAME	DATA DESCRIPTION
Pu	The factored design axial load associated with the Shear Combo.
Mu	The factored design moment associated with the Shear Combo.
Vu	The factored design shear associated with the Shear Combo.
Capacity phi Vc	The shear capacity of the concrete.
Capacity phi Vn	The shear capacity of the section with the specified reinforcing.
Boundary Element Check Data	
Station Location	This is either Top 2-dir or Bot 2-dir and designates the location (top or bottom) of the boundary element check and the direction of force (pier local 2-axis) for which the boundary elements are checked.
B-Zone Length	This is a required length, such as 22.762 inches, or it is *Not Needed*, or it is *Not Checked*. Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is performed by the program because the ratio P_u/P_o is greater than or equal to 0.35.
	When this item is Not Needed or Not Checked, the program fills in the B-Zone Combo, Pu, Mu, Vu, and Pu/Po items with the data from the design load combination that has the largest P_u/P_o value. Otherwise, the program fills in the data from the design load combination that requires the longest boundary zone length.
B-Zone Combo	The design load combination associated with the specified B-Zone Length.
Pu	The factored design axial load associated with the B-Zone Combo.
Mu	The factored design moment associated with the B-Zone Combo.
Vu	The factored design shear associated with the B-Zone Combo.
Pu/Po	The ratio P_u/P_o associated with the B-Zone Combo. Note that if the ratio is greater than or equal to 0.35, the program does not check the boundary zone requirement. See Section 21.6.6 in ACI318-99.

Design of a Uniform Reinforcing or General Reinforcing Section

Display the Pier Design form by right clicking for interactive design of a pier section that is assigned a Uniform or General Reinforcing section and has been designed by the program. General information identifying and locating the pier is displayed at the top of this form. Output information for flexural design, shear design and the boundary element check is also displayed. Several command buttons are on the form. A description of the command buttons is provided at the end of this Technical Note. Table 2 identifies the Data Name and provides a brief Data Description.

Table 2 Output Data for Design of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
General Identification Data	
Story ID	The story level associated with the pier.
Pier ID	The label assigned to the pier.
X Loc	The global X-coordinate of the plan location of the centroid of the *bottom* of the pier.
Y Loc	The global Y-coordinate of the plan location of the centroid of the *bottom* of the pier.
Flexural Design Data	
RLLF	A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.
Station Location	This is either Top or Bottom and designates that the output on the line is for the top or bottom of the pier.
Required Reinf Ratio	The maximum required ratio of reinforcing for the pier, as determined by the program, such that the demand/capacity ratio is 1.0 (approximately). The ratio is equal to the total area of vertical steel in the pier divided by area of the pier. The required reinforcing is assumed to be provided in the same proportions as specified in the Section Designer section.

Table 2 Output Data for Design of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
	For example, assume that the Current Reinf Ratio (see next item) is 0.0200 and the Required Reinf Ratio is 0.0592. In that case, the section should be adequate if you triple the size of each bar that is currently specified in the Section Designer section. Alternatively, you could add more bars.
	Important note: We do not recommend that you use the required reinforcing ratio as the final design result. Instead, we recommend that you use it as a guide in defining a General Reinforcing section, with actual reinforcing that is checked by the program (not designed).

Tip:

Do not confuse the Required Reinforcing Ratio and the Current Reinforcing Ratio. The important item is the Required Reinforcing Ratio.

DATA NAME	DATA DESCRIPTION
Current Reinf Ratio	The ratio of the actual reinforcing specified in the pier section divided by the area of the pier section. This ratio is provided as a benchmark to help you understand how much reinforcing is actually required in the section.

Note:

The area of the pier section that is used in computing the Required Reinf Ratio and the Current Reinf Ratio is the actual area of the pier. This may be different from the transformed area that is reported by Section Designer. See the Section Designer Manual for more information.

DATA NAME	DATA DESCRIPTION
Flexural Combo	The design load combination associated with the specified required reinforcing ratio.
Pu	The factored design axial load associated with the Flexural Combo.
M2u	The factored design moment about the pier local 2-axis associated with the Flexural Combo.
M3u	The factored design moment about the pier local 3-axis associated with the Flexural Combo.

Note:

The flexural design of a Uniform or General pier section is always a PMM design that considers both M2 and M3 bending.

Table 2 Output Data for Design of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
Pier Ag	Gross area of the pier used for flexural calculations.
Shear Design Data	
EQF	A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See EQ Factor in Shear Wall Design ACI318-99 Technical Note 24 Overwrites for more information.
Station Location	This is the Top Leg x and the Bot Leg y where x and y represent the worst-case top and bottom pier legs for shear.
Rebar	Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Shear Combo	The design load combination associated with the specified shear reinforcing.
Pu	The factored design axial load associated with the Shear Combo.
Mu	The factored design moment associated with the Shear Combo.
Vu	The factored design shear associated with the Shear Combo.
Boundary Element Check Data	
Station Location	This is Top Leg x and Bot Leg y where x and y represent the worst-case top and bottom pier legs for boundary zones.
B-Zone Length	This is a required length, such as 22.762 inches, or it is *Not Needed*, or it is *Not Checked*. Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is completed by the program because the ratio P_u/P_o is greater than or equal to 0.35. When this item is Not Needed or Not Checked, the program fills in the B-Zone Combo, Pu, Mu, Vu, and Pu/Po items with the data from the design load combination that has the largest P_u/P_o value. Otherwise, the program fills in the data from the design load combination that requires the longest boundary zone length.

Table 2 Output Data for Design of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
B-Zone Combo	The design load combination associated with the specified B-Zone Length.
Pu	The factored design axial load associated with the B-Zone Combo.
Mu	The factored design moment associated with the B-Zone Combo.
Vu	The factored design shear associated with the B-Zone Combo.
Pu/Po	The ratio P_u/P_o associated with the B-Zone Combo. Note that if the ratio is greater than or equal to 0.35, the program does not check the boundary zone requirement. See Section 21.6.6 in ACI318-99.

Check of a Uniform Reinforcing or General Reinforcing Section

Display the Pier Design form by right clicking for interactive design of a pier section that is assigned a Uniform or General Reinforcing section and is designated to be checked (not designed) by the program. General information identifying and locating the pier is displayed at the top of this form. Output information for the flexural check, shear design and the boundary element check is also displayed. Several command buttons are on the form. A description of the command buttons is provided at the end of this Technical Note. Table 3 identifies the Data Name and provides a brief Data Description.

Table 3 Output Data for Check of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
General Identification Data	
Story ID	The story level associated with the pier.
Pier ID	The label assigned to the pier.
X Loc	The global X-coordinate of the plan location of the centroid of the *bottom* of the pier.
Y Loc	The global Y-coordinate of the plan location of the centroid of the *bottom* of the pier.
Flexural Design Data	
RLLF	A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.
Flexural Combo	The design load combination that yields the largest flexural Demand/Capacity ratio.
Station Location	This is either Top or Bottom designating that the output on the line is for the top or bottom of the pier.
D/C Ratio	The Demand/Capacity ratio associated with the Flexural Combo.
Pu	The factored design axial load associated with the Flexural Combo.
M2u	The factored design moment about the pier local 2-axis associated with the Flexural Combo.
M3u	The factored design moment about the pier local 3-axis associated with the Flexural Combo.
Note: The flexural design of a Uniform or General pier section is always a PMM design that considers both M2 and M3 bending.	
Shear Design Data	
EQF	A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See EQ Factor in Shear Wall Design ACI318-99 Technical Note 24 Overwrites for more information.
Station Location	This is the Top Leg x and the Bot Leg y where x and y represent the worst-case top and bottom pier legs for shear.

Table 3 Output Data for Check of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
Rebar	Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Shear Combo	The design load combination associated with the specified shear reinforcing.
Pu	The factored design axial load associated with the Shear Combo.
Mu	The factored design moment associated with the Shear Combo.
Vu	The factored design shear associated with the Shear Combo.
Boundary Element Check Data	
Station Location	This is Top Leg x and Bot Leg y where x and y represent the worst-case top and bottom pier legs for boundary zones.
B-Zone Length	This is a required length, such as 22.762 inches, or it is *Not Needed*, or it is *Not Checked*. Not Needed indicates that boundary elements are not required. Not Checked means that no check for boundary elements is completed by the program because the ratio P_u/P_o is greater than or equal to 0.35.
	When this item is Not Needed or Not Checked, the program fills in the B-Zone Combo, Pu, Mu, Vu, and Pu/Po items with the data from the design load combination that has the largest P_u/P_o value. Otherwise, the program fills in the data from the design load combination that requires the longest boundary zone length.
B-Zone Combo	The design load combination associated with the specified B-Zone Length.
Pu	The factored design axial load associated with the B-Zone Combo.
Mu	The factored design moment associated with the B-Zone Combo.
Vu	The factored design shear associated with the B-Zone Combo.

Table 3 Output Data for Check of a Uniform or General Section

DATA NAME	DATA DESCRIPTION
Pu/Po	The ratio P_u/P_o associated with the B-Zone Combo. Note that if the ratio is greater than or equal to 0.35, the program does not check the boundary zone requirement. See Section 21.6.6 in ACI318-99.

Interactive Spandrel Design and Review

Right clicking on a spandrel for interactive design displays the Spandrel Design form. Note that a design must have been run for the interactive design mode to be available. To run a design, click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.

General information identifying and locating the spandrel is displayed at the top of this form. Output information for both flexural and shear design is also displayed, and several command buttons are on the form. A description of the command buttons is provided at the end of this Technical Note. Table 4 identifies the Data Name and provides a brief Data Description.

Table 4 Output Data for Interactive Spandrel Design and Review

DATA NAME	DATA DESCRIPTION
General Identification Data	
Story ID	The story level associated with the spandrel.
Spandrel ID	The label assigned to the spandrel.
X Loc	The global X-coordinate of the plan location of the centroid of the *left* end of the spandrel.
Y Loc	The global Y-coordinate of the plan location of the centroid of the *left* end of the spandrel.
Flexural Design Data	
RLLF	A reducible live load acting on a spandrel is multiplied by this factor to obtain the reduced live load.
Top Steel	
Station Location	This is either Left or Right and designates that the output reported is for the left or right end of the spandrel.

Table 4 Output Data for Interactive Spandrel Design and Review

DATA NAME	DATA DESCRIPTION
Top Steel Area	The area of top steel required for the Top Steel Combo. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Top Steel Ratio	The area of top steel divided by the spandrel thickness divided by the distance from the bottom of the spandrel to the centroid of the top steel, as shown in Equation 1. $$\text{Top Steel Ratio} = \frac{A_{s\ top}}{t_s\left(h_s - d_{r-top}\right)} \qquad \text{Eqn. 1}$$
Top Steel Combo	The name of the design load combination that requires the most top steel in the spandrel.
Mu	The factored design moment associated with the Top Steel Combo.
Bottom Steel	
Station Location	This is either Left or Right and designates that the output reported is for the left or right end of the spandrel. Note that the bottom steel is only reported at the ends of the spandrel, not at the center of the spandrel.
Bot Steel Area	The area of bottom steel required for the Bot Steel Combo. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Bot Steel Ratio	The area of bottom steel divided by the spandrel thickness divided by the distance from the top of the spandrel to the centroid of the bottom steel, as shown in Equation 2. $$\text{Bot Steel Ratio} = \frac{A_{s\ top}}{t_s\left(h_s - d_{r-bot}\right)} \qquad \text{Eqn. 2}$$
Bot Steel Combo	The name of the design load combination that requires the most bottom steel in the spandrel.

Table 4 Output Data for Interactive Spandrel Design and Review

DATA NAME	DATA DESCRIPTION
Mu	The factored design moment associated with the Bot Steel Combo.
Shear Design Data	
EQF	A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the spandrel design overwrites. See EQ Factor in Shear Wall Design ACI318-99 Technical Note 24 Overwrites for more information.
Design Data for all Spandrels	
Station Location	This is either Left or Right and designates that the output reported is for the left or right end of the spandrel.
Avert	The area per unit length of vertical shear steel required for the Shear Combo. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Ahoriz	The area per unit length (height) of horizontal shear steel required in the spandrel. If specific rebar area/length units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area/length is displayed in the current units.
Shear Combo	The name of the design load combination that requires the most vertical shear reinforcing steel in the spandrel.
Vu	The factored design shear force at the specified station location associated with the design load combination specified in the Shear Combo column.
Vc	The concrete shear capacity at the specified station location.

Table 4 Output Data for Interactive Spandrel Design and Review

DATA NAME	DATA DESCRIPTION
Note: This additional shear output data is only provided if the "Design is Seismic" item in the spandrel overwrites is set to Yes for the spandrel considered.	
Additional Design Data for Seismic Spandrels Only These items are only displayed if the "Design is Seismic" item in the spandrel overwrites is set to Yes for the spandrel considered.	
Station Location	This is either Left or Right and designates that the output reported is for the left or right end of the spandrel.
Adiag	The area of diagonal shear steel required for the Shear Combo. If specific rebar area units have been specified in the shear wall preferences, those units are displayed in the column heading. If no specific units are displayed in the column heading, the rebar area is displayed in the current units.
Shear Combo	The name of the design load combination that requires the most vertical shear reinforcing steel in the spandrel.
Vu	The factored design shear force at the specified station location associated with the design load combination specified in the Shear Combo column.
Diag Reinf Required	This item is Yes if Vu > $4\sqrt{f_c'}\ bd_{spandrel}$. Otherwise, it is no.

Command Buttons

Combos Button

Clicking the **Combos** button accesses and allows *temporary* revisions to the design load combinations considered for the pier or spandrel. This may be useful, for example, if you want to see the results for one particular load combination. You can temporarily change the considered design load combinations to be only the one you are interested in and review the results.

The changes made here to the considered design load combinations are temporary. They are not saved when you exit the Pier Design or Spandrel Design form, whether you click **OK** or **Cancel** to exit it.

Overwrites Button

Clicking the **Overwrites** button accesses and allows revisions to the pier or spandrel overwrites and enables immediate review of the revised design results. If you modify some overwrites in this mode and you exit both the Pier Design Overwrites or Spandrel Design overwrites form and the Pier Design or Spandrel Design form by clicking their respective **OK** buttons, the changes made to the overwrites are permanently saved.

Exiting the Pier Design or Spandrel Design Overwrites form by clicking the **OK** button temporarily saves changes. Subsequently exiting the Pier Design or Spandrel Design form by clicking the **Cancel** button *does not* save the changes made to the pier or spandrel overwrites.

To permanently save changes to the overwrites, click the **OK** button to exit the Pier Design or Spandrel Design Overwrites, and then click the **OK** button to exit the Pier Design or Spandrel Design form.

Section Top and Section Bot Buttons

These buttons are only visible if you are designing or checking a pier with a Uniform Reinforcing or General Reinforcing section assigned to it. Clicking these buttons opens Section Designer in a locked (read-only) mode, where you can view the pier.

While in Section Designer, you can review the geometry of the section and the size and location of the rebar. However, you cannot make any changes to the section. You can also review the section properties, interaction surface and moment curvature curve.

Important note: The interaction surface and the moment curvature curve are displayed for the section as it is defined in Section Designer. Thus, when you are designing a pier that is assigned a Section Designer section, the interaction surface and moment curvature curve displayed are for the reinforcing (ratio) drawn in Section Designer, *not the required reinforcing ratio reported in the design output.*

When you have finished reviewing the section in Section Designer, close Section Designer to return to the Pier Design form in the main program.

Technical Note 23
Preferences

General

The shear wall design preferences are basic properties that apply to all wall pier and/or spandrel elements. This Technical Note describes shear wall design preferences for ACI318-99. To access the shear wall Preferences form, click the **Options menu > Preferences > Shear Wall Design** command.

Default values are provided for all shear wall design preference items. Thus, it is not required that you specify or change any of the preferences. You should, however, at least review the default values for the preference items to make sure they are acceptable to you.

The preference options are described in Table 1, which uses the following column headings:

- **Item:** The name of the preference item as it appears in the cells at the left side of the Preferences form.
- **Possible Values:** The possible values that the associated preference item can have.
- **Default Value:** The built-in default value that the program assumes for the associated preference item.
- **Description:** A description of the associated preference item.

The Flags and Factors used by the program are listed following Table 1. In addition, an explanation of how to change a preference is provided at the end of this Technical Note.

Table 1 Shear Wall Preferences

Item	Possible Values	Default Value	Description
Design Code	Any code in the program	UCB 97	Design code used for design of concrete shear wall elements (wall piers and spandrels)
Time History Design	Envelopes or Step-by-Step	Envelopes	Toggle for design load combinations that include a time history designed for the envelope of the time history, or designed step-by-step for the entire time history. If a single design load combination has *more than one* time history case in it, that design load combination is designed for the envelopes of the time histories, regardless of what is specified here.
Rebar units	in^2, cm^2, mm^2, current	in^2 or mm^2	Units used for concentrated areas of reinforcing steel. See "Units" in Shear Wall Design Technical Note 1 General Design Information.
Rebar/Length Units	in^2/ft, cm^2/m, mm^2/m, current	in^2/ft or mm^2/m	Units used for distributed areas of reinforcing steel. See "Units" in Shear Wall Design Technical Note 1 General Design Information.
Number of Curves	≥ 4	24	Number of equally spaced interaction curves used to create a full 360-degree interaction surface (this item should be a multiple of four). We recommend that you use 24 for this item. See "Interaction Surface" in Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.
Number of Points	≥ 11	11	Number of points used for defining a single curve in a wall pier interaction surface (this item should be odd). See "Interaction Surface" in Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.
Edge Design PT-max	> 0	0.06	Maximum ratio of tension reinforcing allowed in edge members, PT_{max}. See "Design Condition 1" in Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.

Table 1 Shear Wall Preferences

Item	Possible Values	Default Value	Description
Edge Design PC-max	> 0	0.04	Maximum ratio of compression reinforcing allowed in edge members, PC_{max}. See "Design Condition 1" in Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.
Section Design IP-Max	≥ Section Design IP-Min	0.02	The maximum ratio of reinforcing considered in the design of a pier with a Section Designer section. See the section titled "Designing a Section Designer Pier Section" in Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.
Section Design IP-Min	> 0	0.0025	The minimum ratio of reinforcing considered in the design of a pier with a Section Designer section. See the section titled "Designing a Section Designer Pier Section" in Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.

Flags and Factors

- **Phi-B Factor:** The strength reduction factor for bending in a wall pier or spandrel, ϕ_b.

- **Phi-C Factor:** The strength reduction factor for axial compression in a wall pier, ϕ_c.

- **Phi-Vns Factor:** The strength reduction factor for shear in a wall pier or spandrel for a nonseismic condition, ϕ_{vns}.

- **Phi-Vs Factor:** The strength reduction factor for shear in a wall pier or spandrel for a seismic condition, ϕ_{vs}.

- **PMax Factor:** A factor used to reduce the allowable maximum compressive design strength. See "Formulation of the Interaction Surface" of Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design for more information.

Using the Preferences Form

To view preferences, select the **Options menu > Preferences > Shear Wall Design.** The Preferences form will display. The preference options are displayed in a two-column spreadsheet. The left column of the spreadsheet displays the preference item name. The right column of the spreadsheet displays the preference item value.

To change a preference item, left click the desired preference item in either the left or right column of the spreadsheet. This activates a drop-down box or highlights the current preference value. If the drop-down box appears, select a new value. If the cell is highlighted, type in the desired value. The preference value will update accordingly. You cannot overwrite values in the drop-down boxes.

When you have finished making changes to the shear wall design preferences, click the **OK** button to close the form. You must click the **OK** button for the changes to be accepted by the program. If you click the **Cancel** button to exit the form, any changes made to the preferences are ignored and the form is closed.

ETABS®

SHEAR WALL DESIGN ACI318-99

Technical Note 24
Overwrites

General

The shear wall design overwrites are basic assignments that apply only to those piers or spandrels to which they are assigned. The overwrites for piers and spandrels are separate. This Technical Note describes shear wall overwrites for ACI318-99. Note that the available overwrites change depending on the pier section type (Uniform Reinforcing, General Reinforcing, or Simplified T and C). To access the pier overwrites, select a pier and then click the **Design menu > Shear Wall Design > View/Revise Pier Overwrites** command. To access the spandrel overwrites, select a spandrel and then click the **Design menu > Shear Wall Design > View/Revise Spandrel Overwrites** command.

Default values are provided for all pier and spandrel overwrite items. Thus, you do not need to specify or change any of the overwrites. However, at least review the default values for the overwrite items to make sure they are acceptable. When changes are made to overwrite items, the program applies the changes only to the elements to which they are specifically assigned; that is, to the elements that are selected when the overwrites are changed.

The overwrites are presented in Tables 1 and 2. There are four columns in each table. Each of these columns is described below.

- **Item:** The name of the overwrite item as it appears in the program. To save space in the formes, these names are generally short.
- **Possible Values:** The possible values that the associated overwrite item can have.
- **Default Value:** The default value that the program assumes for the associated overwrite item.
- **Description:** A description of the associated overwrite item.

An explanation of how to change an overwrite is provided at the end of this Technical Note.

Pier Design Overwrites

Table 1: Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Design this Pier	Yes or No	Yes	Toggle for design of the pier when you click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.
LL Reduction Factor	Program calculated, > 0	Program calculated	A reducible live load is multiplied by this factor to obtain the reduced live load. Entering 0 for this item means that it is program calculated. See the subsection entitled "LL Reduction Factor" for more information.
EQ Factor	≥ 0	1	Multiplier on earthquake loads. If 0 is entered for this item, the program resets it to the default value of 1 when the next design is run. See a subsequent section entitled "EQ Factor" for more information.
Design is Seismic	Yes or No	Yes	Toggle for design as seismic or nonseismic. Additional design checks are performed for seismic elements compared to nonseismic elements. Also, in some cases, the strength reduction factors are different.

Table 1: Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Pier Section Type	Uniform Reinforcing, General Reinforcing, Simplified T and C	Uniform Reinforcing	This item indicates the type of pier. The General Reinforcing option is not available unless General pier sections have previously been defined in Section Designer. See "Analysis Sections and Design Sections" in Shear Wall Design Technical Note 1 General Design Information and see Shear Wall Design Technical Note 6 Wall Pier Design Section for more information.
Overwrites Applicable to Uniform Reinforcing Pier Sections			
Edge Bar Name	Any defined bar size	Varies	The size of the uniformly spaced edge bars.
Edge Bar Spacing	>0	12"	The spacing of the uniformly spaced edge bars.
End/Corner Bar Name	Any defined bar size	Varies	The size of end and corner bars.
Clear Cover	>0	1.5"	The clear cover for the edge, end and corners bars.
Material	Any defined concrete material property	Varies	The material property associated with the pier.
Check/Design Reinforcing	Check or Design	Design	This item indicate whether the pier section is to be designed or checked.
Overwrites Applicable to General Reinforcing Pier Sections			
Section Bottom	Any general pier section defined in Section Designer	The first pier in the list of Section Designer piers	Name of a pier section, defined in Section Designer that is assigned to the bottom of the pier.

Table 1: Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Section Top	Any general pier section defined in Section Designer	The first pier in the list of Section Designer piers	Name of a pier section, defined in Section Designer, that is assigned to the top of the pier.
Check/Design Reinforcing	Check or Design	Design	This item indicates whether the pier section is to be designed or checked.
Overwrites Applicable to Simplified T and C Pier Sections			
ThickBot	Program calculated, or > 0	Program calculated	Wall pier thickness at bottom of pier, t_p. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See "How the Program Calculates the Default Dimensions" in Shear Wall Design Technical Note 6 Wall Pier Design Section for more information. Inputting 0 means the item is to be program calculated.
LengthBot	Program calculated, or > 0	Program calculated	Wall pier length at bottom of pier, L_p. See Figure 1 in Technical Note Wall Pier Design Section Shear Wall Design. See "How the Program Calculates the Default Dimensions" in Shear Wall Design Technical Note 6 Wall Pier Design Section for more information. Inputting 0 means the item is to be program calculated.
DB1LeftBot	≥ 0	0	Length of the bottom of a user-defined edge member on the left side of a wall pier, $DB1_{left}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See the subsection below entitled "User-Defined Edge Members" for more information.

Table 1: Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
DB1RightBot	≥ 0	Same as DB1-left-bot	Length of the bottom of a user-defined edge member on the right side of a wall pier, $DB1_{right}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See the subsection entitled "User-Defined Edge Members" for more information.
DB2LeftBot	≥ 0	0	Width of the bottom of a user-defined edge member on the left side of a wall pier, $DB2_{left}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See the subsection entitled "User-Defined Edge Members" for more information.
DB2RightBot	≥ 0	Same as DB2-left-bot	Width of the bottom of a user-defined edge member on the right side of a wall pier, $DB2_{right}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See the subsection entitled "User-Defined Edge Members" for more information.
ThickTop	Program calculated, or > 0	Program calculated	Wall pier thickness at top of pier, t_p. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See "How the Program Calculates the Default Dimensions" in Shear Wall Design Technical Note 6 Wall Pier Design Section for more information. Inputting 0 means the item is to be program calculated.

Table 1: Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
LengthTop	Program calculated, or > 0	Program calculated	Wall pier length at top of pier, L_p. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section. See "How the Program Calculates the Default Dimensions" in Shear Wall Design Technical Note 6 Wall Pier Design Section for more information. Inputting 0 means the item is to be program calculated.
DB1LeftTop	≥ 0	0	Length of the top of a user-defined edge member on the left side of a wall pier, $DB1_{left}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section.
DB1RightTop	≥ 0	Same as DB1-left-bot	Length of the top of a user-defined edge member on the right side of a wall pier, $DB1_{right}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section.
DB2LeftTop	≥ 0	0	Width of the top of a user-defined edge member on the left side of a wall pier, $DB2_{left}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section.
DB2RightTop	≥ 0	Same as DB2-left-bot	Width of the top of a user-defined edge member on the right side of a wall pier, $DB2_{right}$. See Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Section.
Material	Any defined concrete material property	See "Material Properties" in Shear Wall Design Technical Note 6 Wall Pier Design Section	Material property associated with the pier.

Table 1: Pier Design Overwrites

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Edge Design PC-max	> 0	Specified in Preferences	Maximum ratio of compression reinforcing allowed in edge members, PC_{max}. See "Design Condition 1" in Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.
Edge Design PT-max	> 0	Specified in Preferences	Maximum ratio of tension reinforcing allowed in edge members, PT_{max}. See "Design Condition 1" in Shear Wall Design ACI318-99 Technical Note 26 Wall Pier Flexural Design.

LL Reduction Factor

If the LL Reduction Factor is program calculated, it is based on the live load reduction method chosen in the live load reduction preferences, which are set using the **Options menu > Preferences > Live Load Reduction** command. If you specify your own LL Reduction Factor, the program ignores any reduction method specified in the live load reduction preferences and simply calculates the reduced live load for a pier or spandrel by multiplying the specified LL Reduction Factor times the reducible live load.

Note that you can use the **Define menu > Static Load Cases** command to specify that a load case is a reducible live load.

Important Note: The LL reduction factor is ***not*** applied to any load combination that is included in a design load combination. For example, assume you have two static load cases labeled DL and RLL. DL is a dead load and RLL is a reducible live load.

Now assume that you create a design load combination named DESCOMB1 that includes DL and RLL. Then for design load combination DESCOMB1, the RLL load is multiplied by the LL reduction factor.

Next assume that you create a load combination called COMB2 that includes RLL. Now assume that you create a design load combination called

DESCOMB3 that included DL and COMB2. For design load combination DESCOMB3, the RLL load that is part of COMB2 is ***not*** multiplied by the LL reduction factor.

EQ Factor

The EQ (earthquake) factor is a multiplier that is typically applied to the earthquake load in a design load combination. Following are the five types of loads that can be included in a design load combination, along with an explanation of how the EQ factor is applied to each of the load types.

- **Static Load:** The EQ factor is applied to any static loads designated as a Quake-type load. The EQ factor is not applied to any other type of static load.

- **Response Spectrum Case:** The EQ factor is applied to all response spectrum cases.

- **Time History Case:** The EQ factor is applied to all time history cases.

- **Static Nonlinear Case:** The EQ factor is ***not*** applied to any static nonlinear cases.

- **Load Combination:** The EQ factor is ***not*** applied to any load combination that is included in a design load combination. For example, assume you have two static load cases labeled DL and EQ. DL is a dead load and EQ is a quake load.

  Now assume that you create a design load combination named DESCOMB1 that includes DL and EQ. For design load combination DESCOMB1, the EQ load is multiplied by the EQ factor.

  Next assume that you create a load combination called COMB2 that includes EQ. Now assume that you create a design load combination called DESCOMB3 that included DL and COMB2. For design load combination DESCOMB3, the EQ load that is part of COMB2 is ***not*** multiplied by the EQ factor.

The EQ factor allows you to design different members for different levels of earthquake loads in the same run. It also allows you to specify member-specific reliability/redundancy factors that are required by some codes. The ρ factor specified in Section 1630.1.1 of the 1997 UBC is an example of this.

User-Defined Edge Members

When defining a user-defined edge member, you must specify both a nonzero value for DB1 and a nonzero value for DB2. If either DB1 or DB2 is specified as zero, the edge member width is taken the same as the pier thickness and the edge member length is determined by the program.

Spandrel Design Overwrites

Table 2 Spandrel Design Overwrites

Spandrel Overwrite Item	Possible Values	Default Value	Spandrel Overwrite Description
Design this Spandrel	Yes or No	Yes	Toggle for design of the spandrel when you click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.
LL Reduction Factor	Program calculated, > 0	Program calculated	A reducible live load is multiplied by this factor to obtain the reduced live load. Entering 0 for this item means that it is program calculated. See the subsection entitled "LL Reduction Factor" for more information.
EQ Factor	≥ 0	1	Multiplier on earthquake loads. If 0 is entered for this item, the program resets it to the default value of 1 when the next design is run. See the previous subsection entitled "EQ Factor" for more information.
Design is Seismic	Yes or No	Yes	Toggle for design as seismic or nonseismic. Additional design checks are performed for seismic elements compared to nonseismic elements. Also, in some cases the strength reduction factors are different.
Length	Program calculated, or > 0	Program calculated	Wall spandrel length, L_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated.

Table 2 Spandrel Design Overwrites

Spandrel Overwrite Item	Possible Values	Default Value	Spandrel Overwrite Description
ThickLeft	Program calculated, or > 0	Program calculated	Wall spandrel thickness at left side of spandrel, t_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated.
DepthLeft	Program calculated, or > 0	Program calculated	Wall spandrel depth at left side of spandrel, h_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated.
CoverBotLeft	Program calculated, or > 0	Program calculated	Distance from bottom of spandrel to centroid of bottom reinforcing, $d_{r\text{-bot left}}$ on left side of beam. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated as $0.1h_s$.
CoverTopLeft	Program calculated, or > 0	Program calculated	Distance from top of spandrel to centroid of top reinforcing, $d_{r\text{-top left}}$ on left side of beam. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated as $0.1h_s$.
SlabWidthLeft	≥ 0	0	Slab width for T-beam at left end of spandrel, b_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections.
SlabDepthLeft	≥ 0	0	Slab depth for T-beam at left end of spandrel, d_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections.

Table 2 Spandrel Design Overwrites

Spandrel Overwrite Item	Possible Values	Default Value	Spandrel Overwrite Description
ThickRight	Program calculated, or > 0	Program calculated	Wall spandrel thickness at right side of spandrel, t_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated.
DepthRight	Program calculated, or > 0	Program calculated	Wall spandrel depth at right side of spandrel, h_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated.
CoverBotRight	Program calculated, or > 0	Program calculated	Distance from bottom of spandrel to centroid of bottom reinforcing, $d_{r\text{-bot right}}$ on right side of beam. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated as $0.1h_s$.
Cover-TopRight	Program calculated, or > 0	Program calculated	Distance from top of spandrel to centroid of top reinforcing, $d_{r\text{-top right}}$ on right side of beam. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections. Inputting 0 means the item is to be program calculated as $0.1h_s$.
SlabWidth-Right	≥ 0	0	Slab width for T-beam at right end of spandrel, b_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections.
SlabDepth-Right	≥ 0	0	Slab depth for T-beam at right end of spandrel, d_s. See Figure 1 in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections.

Table 2 Spandrel Design Overwrites

Spandrel Overwrite Item	Possible Values	Default Value	Spandrel Overwrite Description
Material	Any defined concrete material property	See "Default Design Material Property" in Shear Wall Design Technical Note 7 Wall Spandrel Design Sections	Material property associated with the spandrel.
Consider Vc	Yes or No	Yes	Toggle switch to consider V_c (concrete shear capacity) when computing the shear capacity of the spandrel.

Making Changes in the Overwrites Form

To access the pier overwrites, select a pier and then click the **Design menu > Shear Wall Design > View/Revise Pier Overwrites** command. To access the spandrel overwrites, select a spandrel and then click the **Design menu > Shear Wall Design > View/Revise Spandrel Overwrites** command.

The pier or spandrel overwrites are displayed in the form with a column of check boxes and a two-column spreadsheet. The left column of the spreadsheet contains the name of the overwrite item. The right column of the spreadsheet contains the overwrites values.

Initially, the check boxes in the Pier or Spandrel Design form are all unchecked and all of the cells in the spreadsheet have a gray background to indicate that they are inactive and the items in the cells cannot be changed. The names of the overwrite items are displayed in the first column of the spreadsheet. The values of the overwrite items are visible in the second column of the spreadsheet if only one pier or spandrel was selected before the overwrites form was accessed. If multiple piers or spandrels were selected, no values show for the overwrite items in the second column of the spreadsheet.

After selecting one or multiple piers or spandrels, check the box to the left of an overwrite item to change it. Then left click in either column of the spreadsheet to activate a drop-down box or highlight the contents in the cell in the right column of the spreadsheet. If the drop-down box appears, select a value from the box. If the cell contents is highlighted, type in the desired value. The overwrite will reflect the change. You cannot change the values of the drop-down boxes.

When changes to the pier or spandrel overwrites have been completed, click the **OK** button to close the form. The program then changes all of the overwrite items whose associated check boxes are checked for the selected pier(s) or spandrel(s). You *must* click the **OK** button for the changes to be accepted by the program. If you click the **Cancel** button to exit the form, any changes made to the overwrites are ignored and the form is closed.

ETABS®

SHEAR WALL DESIGN ACI318-99

Technical Note 25
Design Load Combinations

This Technical Note defines the default concrete shear wall design load combinations. Use the default shear wall design load combinations, define your own combinations, or use both default and user-defined combinations. Modify the default design load combinations and delete them as necessary.

Note:

The program automatically creates code-specific design load combinations for shear wall design.

Default Design Load Combinations

The design load combinations automatically created by the program for concrete shear wall design are given by Equations 1 through 10.

$1.4\Sigma DL$ Eqn. 1

$1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL)$ Eqn. 2

$0.75[1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL) + 1.7WL]$ Eqn. 3

$0.75[1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL) - 1.7WL]$ Eqn. 4

$0.9\Sigma DL + 1.3WL$ Eqn. 5

$0.9\Sigma DL - 1.3WL$ Eqn. 6

$1.1\ [1.2\Sigma DL + 0.5(\Sigma LL + \Sigma RLL) + 1.0E]$ Eqn. 7

$1.1\ [1.2\Sigma DL + 0.5(\Sigma LL + \Sigma RLL) - 1.0E]$ Eqn. 8

$1.1\ (0.9\Sigma DL + 1.0E)$ Eqn. 9

$1.1\ (0.9\Sigma DL - 1.0E)$ Eqn. 10

In Equations 1 through 10,

ΣDL = The sum of all dead load (DL) load cases defined for the model.

ΣLL = The sum of all live load (LL) load cases defined for the model. Note that this includes roof live loads as well as floor live loads.

ΣRLL = The sum of all reducible live load (RLL) load cases defined for the model.

WL = Any single wind load (WL) load case defined for the model.

E = Any single earthquake load (E) load case defined for the model.

Dead Load Component

The dead load component of the default design load combinations consists of the sum of all dead loads multiplied by the specified factor. Individual dead load cases are not considered separately in the default design load combinations.

See the description of the earthquake load component later in this Technical Note for additional information.

Live Load Component

The live load component of the default design load combinations consists of the sum of all live loads, both reducible and unreducible, multiplied by the specified factor. Individual live load cases are not considered separately in the default design load combinations.

Wind Load Component

The wind load component of the default design load combinations consists of the contribution from a single wind load case. Thus, if multiple wind load cases are defined in the program model, each of Equations 10-3 through 10-6 will contribute multiple design load combinations, one for each wind load case that is defined.

Earthquake Load Component

The earthquake load component of the default design load combinations consists of the contribution from a single earthquake load case. Thus, if multiple earthquake load cases are defined in the program model, each of Equations 7 through 10 will contribute multiple design load combinations, one for each earthquake load case that is defined.

The earthquake load cases considered when creating the default design load combinations include all static load cases that are defined as earthquake loads and all response spectrum cases. Default design load combinations are not created for time history cases or for static nonlinear cases.

Design Load Combinations That Include a Response Spectrum

In the program all response spectrum cases are assumed to be earthquake load cases. Default design load combinations are created that include the response spectrum cases.

The output from a response spectrum is all positive. *Any program shear wall design load combination that includes a response spectrum load case is checked for all possible combinations of signs on the response spectrum values.* Thus, when checking shear in a wall pier or a wall spandrel, the response spectrum contribution of shear to the design load combination is considered once as a positive shear and then a second time as a negative shear. Similarly, when checking moment in a wall spandrel, the response spectrum contribution of moment to the design load combination is considered once as a positive moment and then a second time as a negative moment. When checking the flexural behavior of a two-dimensional wall pier or spandrel, four possible combinations are considered for the contribution of response spectrum load to the design load combination. They are:

- +P and +M
- +P and -M
- -P and +M
- -P and -M

where P is the axial load in the pier and M is the moment in the pier. Similarly, eight possible combinations of P, M2 and M3 are considered for three-dimensional wall piers.

Note that based on the above, Equations 7 and 8 are redundant for a load combination with a response spectrum, and similarly, Equations 9 and 10 are redundant for a load combination with a response spectrum. For this reason, the program only creates default design load combinations based on Equations 7 and 9 for response spectra. Default design load combinations using Equations 8 and 10 are not created for response spectra.

Design Load Combinations that Include Time History Results

The default shear wall design load combinations do not include any time history results. To include time history forces in a design load combination, define the load combination yourself.

When your design load combination includes time history results, you can either design for the envelope of those results or you can do a design for each step of the time history. You specify the type of time history design in the shear wall design preferences. See Shear Wall Design ACI318-99 Technical Note 23 Preferences for more information.

When you design for the envelopes, the design is for the maximum of each response quantity (axial load, moment, etc.) as if they occurred simultaneously. Typically, this is not the realistic case, and in some instances, it may be unconservative. Designing for each step of a time history gives you the correct correspondence between different response quantities, but designing for each step can be very time consuming.

When the program gets the envelope results for a time history, it gets a maximum and a minimum value for each response quantity. Thus, for wall piers it gets maximum and minimum values of axial load, shear and moment; and for wall spandrels, it gets maximum and minimum values of shear and moment. For a design load combination in the the program shear wall design module, any load combination that includes a time history load case in it is checked for all possible combinations of maximum and minimum time history design values. Thus, when checking shear in a wall pier or a wall spandrel, the time history contribution of shear to the design load combination is considered once as a maximum shear and then a second time as a minimum shear. Similarly, when checking moment in a wall spandrel, the time history contribution of moment to the design load combination is considered once as a maximum moment and then a second time as a minimum moment. When checking the flexural behavior of a wall pier, four possible combinations are considered for the contribution of time history load to the design load combination. They are:

- P_{max} and M_{max}

- P_{max} and M_{min}
- P_{min} and M_{max}
- P_{min} and M_{min}

where P is the axial load in the pier and M is the moment in the pier.

If a single design load combination has more than one time history case in it, that design load combination is designed for the envelopes of the time histories, regardless of what is specified for the Time History Design item in the preferences.

Design Load Combinations That Include Static Nonlinear Results

The default shear wall design load combinations do not include any static nonlinear results. To include static nonlinear results in a design load combination, define the load combination yourself.

If a design load combination includes a single static nonlinear case and nothing else, the design is performed for each step of the static nonlinear analysis. Otherwise, the design is only performed for the last step of the static nonlinear analysis.

ETABS® CSI

SHEAR WALL DESIGN ACI318-99

Technical Note 26
Wall Pier Flexural Design

Overview

This Technical Note describes how the program designs and checks concrete wall piers for flexural and axial loads using ACI318-99. The Technical Note is presented in three main sections. First we describe how the program *designs* piers that are specified by a Simplified Section. Next we describe how the program *checks* piers that are specified by a Section Designer Section. Then we describe how the program *designs* piers that are specified by a Section Designer Section.

For both designing and checking piers, it is important that you understand the local axis definition for the pier. Access the local axes assignments using the Assign menu.

Designing a Simplified Pier Section

This section discusses how the program designs a pier that is assigned a simplified section. The geometry associated with the simplified section is illustrated in "Simplified Pier Design Dimensions and Properties" of Shear Wall Design Technical Note 6 Wall Pier Design Sections. The pier geometry is defined by a length, thickness and size of the edge members at each end of the pier (if any).

If no specific edge member dimensions have been specified by the user, the program assumes that the edge member is the same width as the wall, and the program determines the required length of the edge member. In all cases, whether the edge member size is user-specified or program-determined, the program reports the required area of reinforcing steel at the center of the edge member. This section describes how the program-determined length of the edge member is determined and how the program calculates the required reinforcing at the center of the edge member.

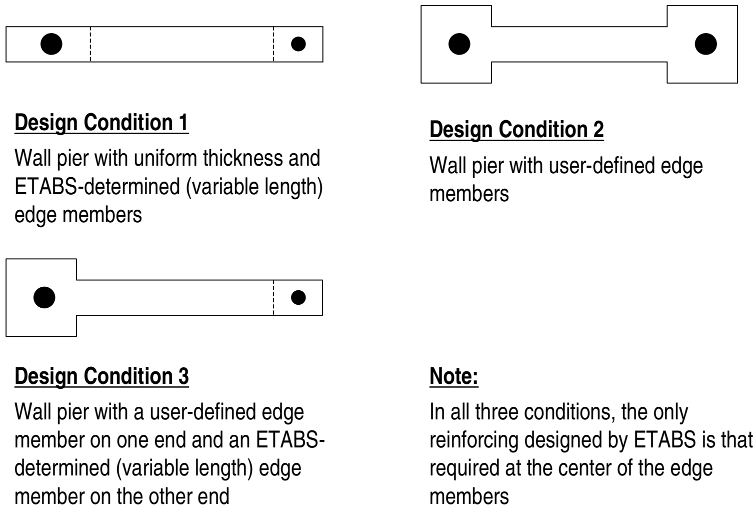


Figure 1: Design Conditions for Simplified Wall Piers

There are three possible design conditions for a simplified wall pier. These conditions, illustrated in Figure 1, are:

1. The wall pier has program-determined (variable length and fixed width) edge members on each end.

2. The wall pier has user-defined (fixed length and width) edge members on each end.

3. The wall pier has a program-determined (variable length and fixed width) edge member on one end and a user-defined (fixed length and width) edge member on the other end.

Design Condition 1

Design condition 1 applies to a wall pier with uniform design thickness and program-determined edge member length. For this design condition, the design algorithm focuses on determining the required size (length) of the edge members while limiting the compression and tension reinforcing located at the center of the edge members to user-specified maximum ratios. The maximum ratios are specified in the shear wall design preferences and the pier design overwrites as Edge Design PC-Max and Edge Design PT-Max.

Consider the wall pier shown in Figure 2. For a given design section, say the top of the wall pier, the wall pier for a given design load combination is designed for a factored axial force $P_{u\text{-}top}$ and a factored moment $M_{u\text{-}top}$.

The program initiates the design procedure by assuming an edge member at the left end of the wall of thickness t_p and width $B_{1\text{-}left}$, and an edge member at the right end of the wall of thickness t_p and width $B_{1\text{-}right}$. Initially $B_{1\text{-}left}$ = $B_{1\text{-}right}$ = t_p.

The moment and axial force are converted to an equivalent force set $P_{left\text{-}top}$ and $P_{right\text{-}top}$ using the relationships shown in Equations 1a and 1b. (Similar equations apply at the bottom of the pier).

$$P_{left-top} = \frac{P_{u-top}}{2} + \frac{M_{u-top}}{\left(L_p - 0.5B_{1-left} - 0.5B_{1-right}\right)} \quad \text{Eqn. 1a}$$

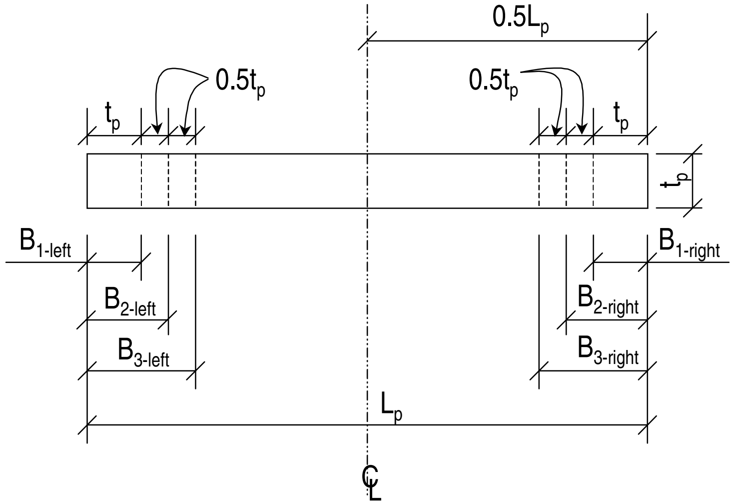
$$P_{right-top} = \frac{P_{u-top}}{2} - \frac{M_{u-top}}{\left(L_p - 0.5B_{1-left} - 0.5B_{1-right}\right)} \quad \text{Eqn. 1b}$$

For any given loading combination, the net values for $P_{left\text{-}top}$ and $P_{right\text{-}top}$ could be tension or compression.

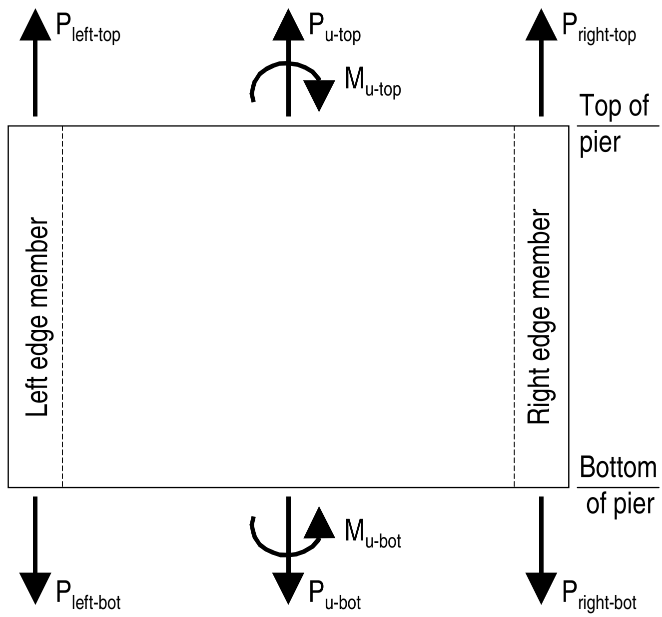
Note that for dynamic loads, $P_{left\text{-}top}$ and $P_{right\text{-}top}$ are obtained at the modal level and the modal combinations are made, before combining with other loads. Also for design loading combinations involving SRSS, the $P_{left\text{-}top}$ and $P_{right\text{-}top}$ forces are obtained first for each load case before the combinations are made.

If any value of $P_{left\text{-}top}$ or $P_{right\text{-}top}$ is tension, the area of steel required for tension, A_{st}, is calculated as:

$$A_{st} = \frac{P}{\phi_b f_y} \quad \text{Eqn. 2}$$



Wall Pier Plan



Wall Pier Elevation

Figure 2: Wall Pier for Design Condition 1

If any value of $P_{left\text{-}top}$ or $P_{right\text{-}top}$ is compression, for section adequacy, the area of steel required for compression, A_{sc}, must satisfy the following relationship.

$$\text{Abs}(P) = (\text{Pmax Factor})\,\phi_c\,[0.85f'_c\,(A_g - A_{sc}) + f_y A_{sc}] \qquad \text{Eqn. 3}$$

where P is either $P_{left\text{-}top}$ or $P_{right\text{-}top}$, $A_g = t_p B_1$ and the Pmax Factor is defined in the shear wall design preferences (the default is 0.80). In general, we recommend that you use the default value. From Equation 3,

$$A_{sc} = \frac{\dfrac{\text{Abs}(P)}{(\text{Pmax Factor})\,\varphi_c} - 0.85f'_c A_g}{f_y - 0.85f'_c} \qquad \text{Eqn. 4}$$

If A_{sc} calculates as negative, no compression reinforcing is needed.

The maximum tensile reinforcing to be packed within the t_p times B_1 concrete edge member is limited by:

$$A_{st\text{-}max} = PT_{max} t_p B_1 \qquad \text{Eqn. 5}$$

Similarly, the compression reinforcing is limited by:

$$A_{sc\text{-}max} = PC_{max} t_p B_1 \qquad \text{Eqn. 6}$$

If A_{st} is less than or equal to $A_{st\text{-}max}$ and A_{sc} is less than or equal to $A_{sc\text{-}max}$, the program will proceed to check the next loading combination; otherwise the program will increment the appropriate B_1 dimension (left, right or both depending on which edge member is inadequate) by one-half of the wall thickness to B_2 (i.e., $1.5t_p$) and calculate new values for $P_{left\text{-}top}$ and $P_{right\text{-}top}$ resulting in new values of A_{st} and A_{sc}. This iterative procedure continues until A_{st} and A_{sc} are within the allowed steel ratios for all design load combinations.

If the value of the width of the edge member B increments to where it reaches a value larger than or equal to $L_p/2$, the iteration is terminated and a failure condition is reported.

This design algorithm is an approximate but convenient algorithm. Wall piers that are declared overstressed using this algorithm could be found to be adequate if the reinforcing steel is user-specified and the wall pier is accurately evaluated using interaction diagrams.

Design Condition 2

Design condition 2 applies to a wall pier with user-specified edge members at each end of the pier. The size of the edge members is assumed to be fixed, that is, the program does not modify them. For this design condition, the design algorithm determines the area of steel required in the center edge members and checks if that area gives reinforcing ratios less than the user-specified maximum ratios. The design algorithm used is the same as described for condition 1; however, no iteration is required.

Design Condition 3

Design condition 3 applies to a wall pier with a user-specified (fixed dimension) edge member at one end of the pier and a variable length (program-determined) edge member at the other end. The width of the variable length edge member is equal to the width of the wall.

The design is similar to that which has previously been described for design conditions 1 and 2. The size of the user-specified edge member is not changed. Iteration only occurs on the size of the variable length edge member.

Checking a General or Uniform Reinforcing Pier Section

When you specify that a General Reinforcing or Uniform Reinforcing pier section is to be checked, the program creates an interaction surface for that pier and uses that interaction surface to determine the critical flexural demand/capacity ratio for the pier. This section describes how the program generates the interaction surface for the pier and how it determines the demand/capacity ratio for a given design load combination.

Note:

In this program, the interaction surface is defined by a series of PMM interaction curves that are equally spaced around a 360 degree circle.

Interaction Surface

General

In this program, a three-dimensional interaction surface is defined with reference to the P, M2 and M3 axes. The surface is developed using a series of interaction curves that are created by rotating the direction of the pier neutral axis in equally spaced increments around a 360 degree circle. For example, if 24 PMM curves are specified (the default), there is one curve every 360°/24 curves = 15°. Figure 3 illustrates the assumed orientation of the pier neutral axis and the associated sides of the neutral axis where the section is in tension (designated T in the figure) or compression (designated C in the figure) for various angles.

Note that the orientation of the neutral axis is the same for an angle of θ and θ + 180°. Only the side of the neutral axis where the section is in tension or compression changes. We recommend that you use 24 interaction curves (or more) to define a three-dimensional interaction surface.

Each PMM interaction curve that makes up the interaction surface is numerically described by a series of discrete points connected by straight lines. The coordinates of these points are determined by rotating a plane of linear strain about the neutral axis on the section of the pier. Details of this process are described later in this Technical Note in the section entitled "Details of the Strain Compatibility Analysis."

By default, 11 points are used to define a PMM interaction curve. You can change this number in the preferences, specifying any odd number of points greater than or equal to 11, to be used in creating the interaction curve. If you input an even number for this item in the preferences, the program will increment up to the next higher odd number.

Note that when creating an interaction surface for a two-dimensional wall pier, the program considers only two interaction curves—the 0° curve and the 180° curve—regardless of the number of curves specified in the preferences. Furthermore, only moments about the M3 axis are considered for two-dimensional walls.

Formulation of the Interaction Surface

The formulation of the interaction surface in this program is based consistently on the basic principles of ultimate strength design given in Sections 10.2 and 10.3 of ACI318-99.

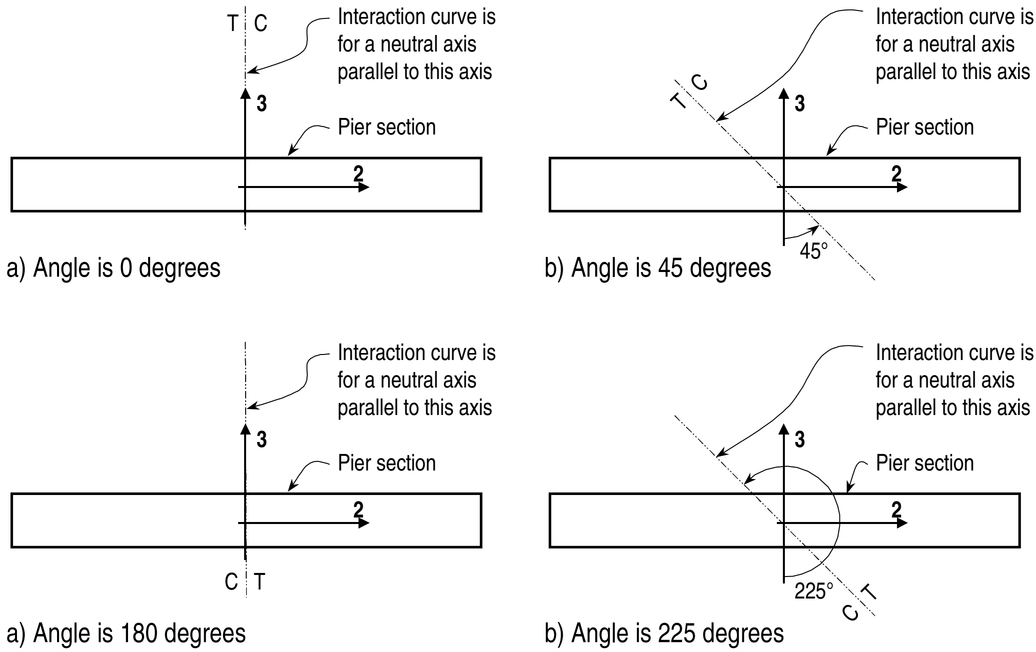


Figure 3: Orientation of the Pier Neutral Axis for Various Angles

The program uses the requirements of force equilibrium and strain compatibility to determine the nominal axial load and moment strength (P_n, $M2_n$, $M3_n$) of the wall pier. This nominal strength is then multiplied by the appropriate strength reduction factor, ϕ, to obtain the design strength (ϕP_n, $\phi M2_n$, $\phi M3_n$) of the pier. For the pier to be deemed adequate, the required strength (P_u, $M2_u$, $M3_u$) must be less than or equal to the design strength, as indicated in Equation 7.

$$(P_u, M2_u, M3_u) \le (\phi P_n, \phi M2_n, \phi M3_n) \qquad \text{Eqn. 7}$$

The effects of the strength reduction factor, ϕ, are included in the generation of the interaction curve. The strength reduction factor, ϕ, for high axial compression, with or without moment, is by default assumed to be equal to ϕ_c. For low values of axial compression, ϕ is increased linearly from ϕ_c to ϕ_b as the required axial strength, $P_u = \phi P_n$, decreases from the smaller of $0.10f'_cA_g$ or ϕP_b to zero, where:

ϕ_c = Strength reduction factor for axial compression in a wall pier. The default value is 0.70.

ϕ_b = Strength reduction factor for bending. The default value is 0.90.

P_b = The axial load at the balanced strain condition where the tension reinforcing reaches the strain corresponding to its specified yield strength, f_y, just as the concrete reaches its assumed ultimate strain of 0.003.

Note:

Strength reduction factors are specified in the shear wall design preference.

In cases involving axial tension, the strength reduction factor, ϕ, is by default equal to ϕ_b. You can revise the strength reduction factors ϕ_c and ϕ_b in the preferences and the overwrites.

The theoretical maximum compressive force that the wall pier can carry, assuming the ϕ_c factor is equal to 1, is designated P_{oc} and is given by Equation 8.

$$P_{oc} = [0.85f'_c\,(A_g - A_s) + f_yA_s] \qquad \text{Eqn. 8}$$

The theoretical maximum tension force that the wall pier can carry, assuming the ϕ_b factor is equal to 1, is designated P_{ot} and is given by Equation 9.

$$P_{ot} = f_yA_s \qquad \text{Eqn. 9}$$

If the wall pier geometry and reinforcing is symmetrical in plan, the moments associated with both P_{oc} and P_{ot} are zero. Otherwise, there will be a moment associated with both P_{oc} and P_{ot}.

The ACI318-99 limits the maximum compressive design strength, ϕ_cP_n, to the value given by P_{max} in Equation 10.

$$P_{max} = 0.80\phi_cP_{oc} = 0.80\phi[0.85f'_c\,(A_g - A_s) + f_yA_s] \qquad \text{Eqn. 10}$$

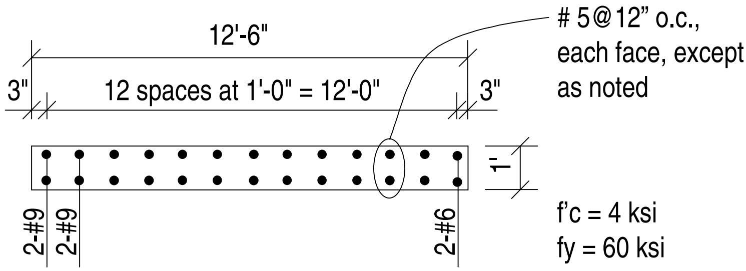


Figure 4: Example Two-Dimensional Wall Pier With Unsymmetrical Reinforcing

Note that the equation defining P_{max} reduces P_{oc} not only by a strength reduction factor, ϕ_c, but also by an additional factor of 0.80. In the preferences, this factor is called the Pmax Factor, and you can specify different values for it if desired. In all ACI318-99 code designs, it is prudent to consider this factor to be 0.80 as required by the code.

Note:

You can specify the number of points to be used for creating interaction diagrams in the shear wall preferences and overwrites.

As previously mentioned, by default, 11 points are used to define a single interaction curve. When creating a single interaction curve, the program includes the points at P_b, P_{oc} and P_{ot} on the interaction curve. Half of the remaining number of specified points on the interaction curve occur between P_b and P_{oc} at approximately equal spacing along the ϕP_n axis. The other half of the remaining number of specified points on the interaction curve occur between P_b and P_{ot} at approximately equal spacing along the ϕP_n axis.

Figure 4 shows a plan view of an example two-dimensional wall pier. Notice that the concrete is symmetrical but the reinforcing is not symmetrical in this example. Figure 5 shows several interaction surfaces for the wall pier illustrated in Figure 4. Note the following about Figure 5:

- Because the pier is two-dimensional, the interaction surface consists of two interaction curves. One curve is at 0° and the other is at 180°. Only M3 moments are considered because this is a two-dimensional example.

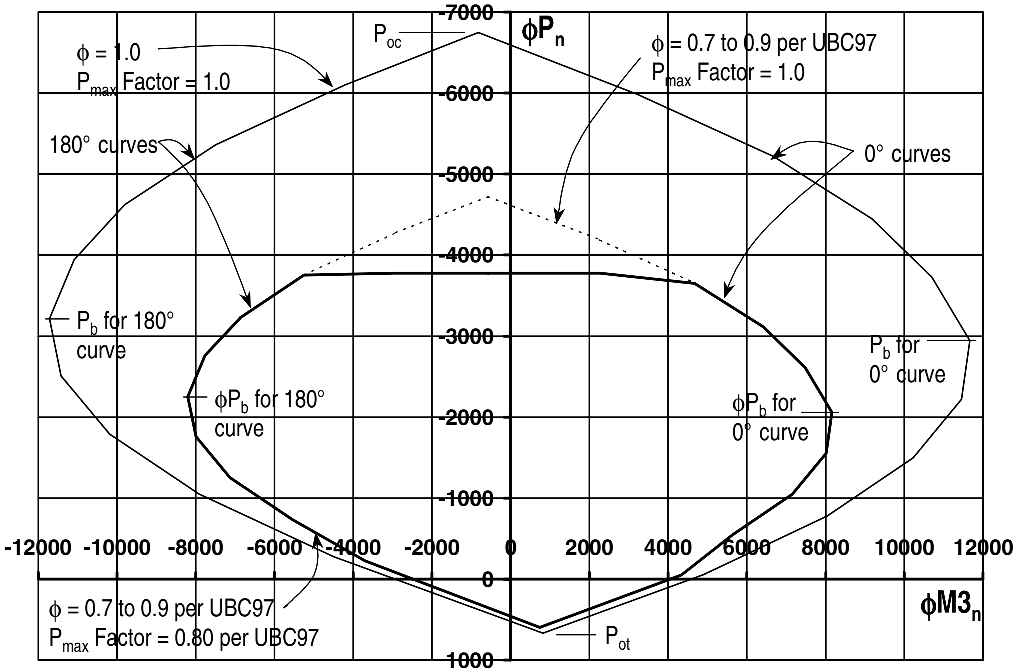


Figure 5: Interaction Curves for Example Wall Pier Shown in Figure 4

- In this program, compression is negative and tension is positive.
- The 0° and 180° interaction curves are not symmetric because the wall pier reinforcing is not symmetric.
- The smaller interaction surface (drawn with a heavier line) has both the strength reduction factors and the Pmax Factor, as specified by ACI318-99.
- The dashed line shows the effect of setting the Pmax Factor to 1.0.
- The larger interaction surface has both the strength reduction factor and the Pmax Factor set to 1.0.
- The interaction surfaces shown are created using the default value of 11 points for each interaction curve.

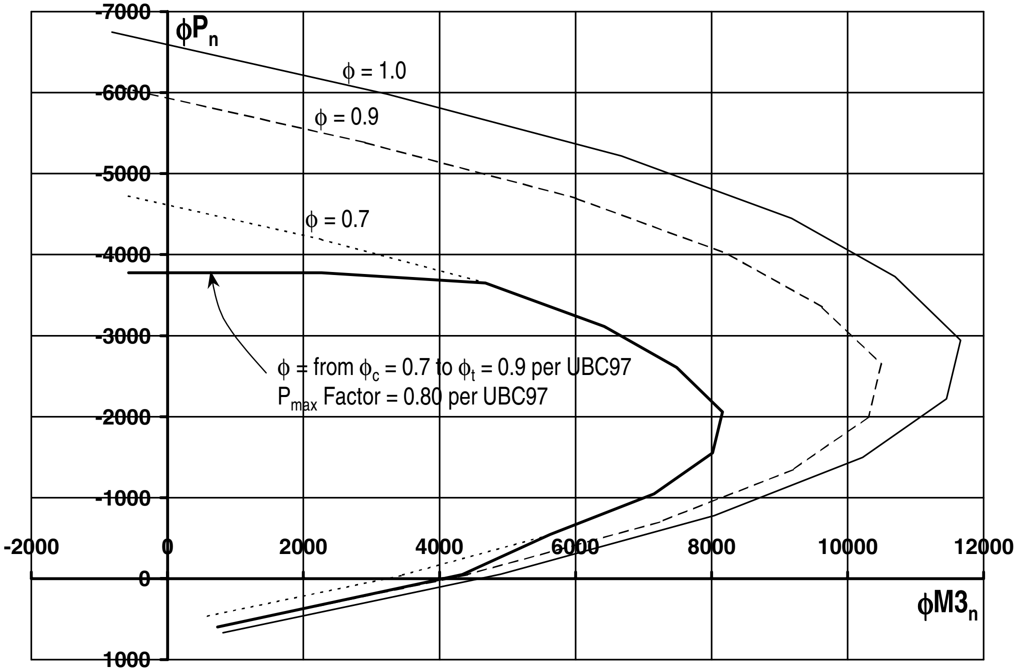


Figure 6: Interaction Curves for Example Wall Pier Shown in Figure 4

Figure 6 shows the 0° interaction curves for the wall pier illustrated in Figure 4. Additional interaction curves are also added to Figure 6. The smaller, heavier curve in Figure 6 has the strength reduction factor and the Pmax Factor as specified in ACI318-99. The other three curves, which are plotted for ϕ = 0.7, 0.9 and 1.0, all have Pmax Factors of 1.0. The purpose of showing these interaction curves is to explain how the program creates the interaction curve. Recall that the strength reduction factors 0.7 and 0.9 are actually ϕ_c and ϕ_b, and that their values can be revised in the overwrites if desired.

Details of the Strain Compatibility Analysis

As previously mentioned, the program uses the requirements of force equilibrium and strain compatibility to determine the nominal axial load and moment strength (P_n, $M2_n$, $M3_n$) of the wall pier. The coordinates of these points are determined by rotating a plane of linear strain on the section of the wall pier.

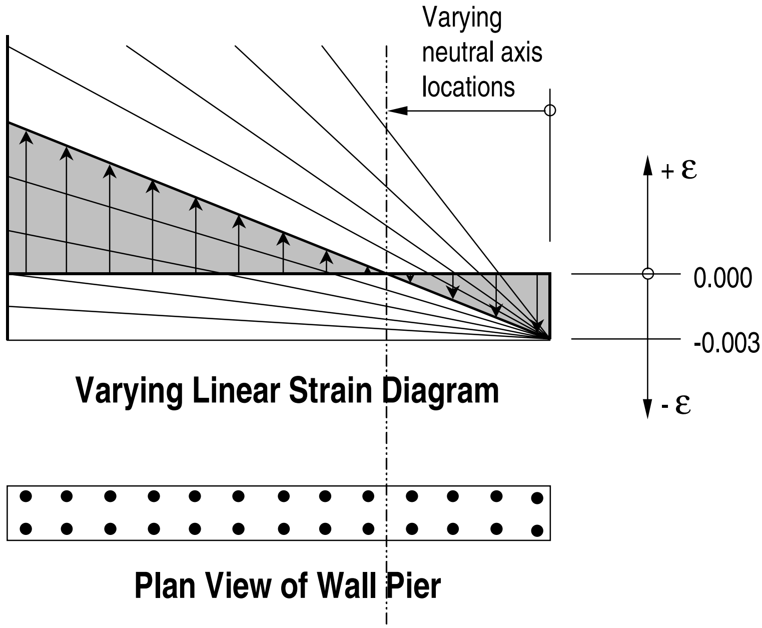


Figure 7: Varying Planes of Linear Strain

Figure 7 illustrates varying planes of linear strain such as those that the program considers on a wall pier section for a neutral axis orientation angle of 0 degrees. In these planes, the maximum concrete strain is always taken as -0.003 and the maximum steel strain is varied from -0.003 to plus infinity. (Recall that in this program compression is negative and tension is positive.) When the steel strain is -0.003, the maximum compressive force in the wall pier, P_{oc}, is obtained from the strain compatibility analysis. When the steel strain is plus infinity, the maximum tensile force in the wall pier, P_{ot}, is obtained. When the maximum steel strain is equal to the yield strain for the reinforcing (e.g., 0.00207 for f_y = 60 ksi), P_b is obtained.

Figure 8 illustrates the concrete wall pier stress-strain relationship that is obtained from a strain compatibility analysis of a typical plane of linear strain shown in Figure 7.

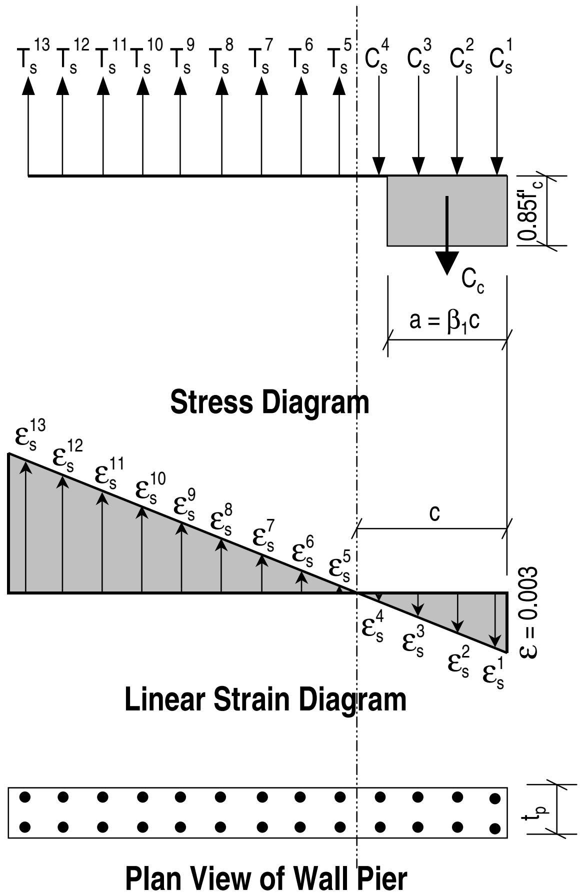


Figure 8: Wall Pier Stress-Strain Relationship

In Figure 8 the compressive stress in the concrete, C_c, is calculated using Equation 11.

$$C_c = 0.85f'_c\beta_1 c t_p \quad \text{Eqn. 11}$$

In Figure 7, the value for maximum strain in the reinforcing steel is assumed. Then the strain in all other reinforcing steel is determined based on the assumed plane of linear strain. Next the stress in the reinforcing steel is calculated using Equation 12, where ε_s is the strain, E_s is the modulus of elasticity, σ_s is the stress, and f_y is the yield stress of the reinforcing steel.

$$\sigma_s = \varepsilon_s E_s \le f_y \qquad \text{Eqn. 12}$$

The force in the reinforcing steel (T_s for tension or C_s for compression) is calculated using Equation 13 where:

$$T_s \text{ or } C_s = \sigma_s A_s \qquad \text{Eqn. 13}$$

For the given distribution of strain, the value of ϕP_n is calculated using Equation 14.

$$\phi P_n = \phi(\Sigma T_s - C_c - \Sigma C_s) \le P_{max} \qquad \text{Eqn. 14}$$

In Equation 14, the tensile force T_s and the compressive forces C_c and C_s are all positive. If ϕP_n is positive, it is tension, and if it is negative, it is compression. The term P_{max} is calculated using Equation 10.

The value of $\phi M2_n$ is calculated by summing the moments due to all of the forces about the pier local 2-axis. Similarly, the value of $\phi M3_n$ is calculated by summing the moments due to all of the forces about the pier local 3-axis. The forces whose moments are summed to determine $\phi M2_n$ and $\phi M3_n$ are ϕP_n, ϕC_c, all of the ϕT_s forces and all of the ϕC_s forces.

The ϕP_n, $\phi M2_n$ and $\phi M3_n$ values calculated as described above make up one point on the wall pier interaction diagram. Additional points on the diagram are obtained by making different assumptions for the maximum steel stress; that is, considering a different plane of linear strain, and repeating the process.

When one interaction curve is complete, the next orientation of the neutral axis is assumed and the points for the associated new interaction curve are calculated. This process continues until the points for all of the specified curves have been calculated.

Again, note that for two-dimensional pier design M2 is ignored.

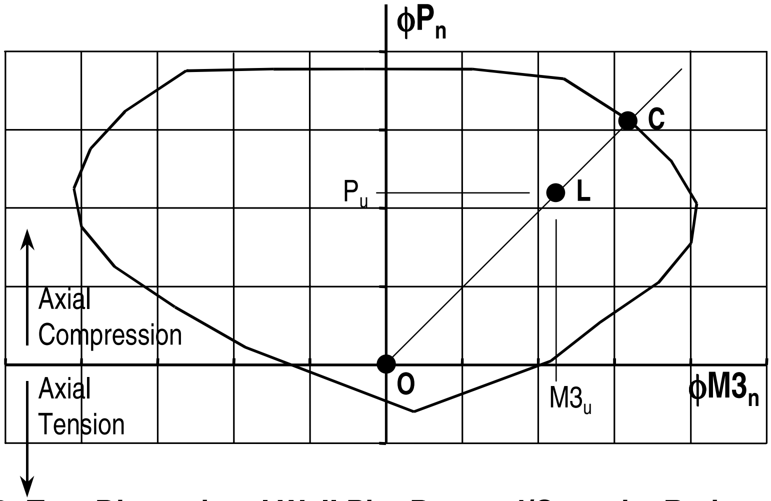


Figure 9: Two-Dimensional Wall Pier Demand/Capacity Ratio

Wall Pier Demand/Capacity Ratio

Refer to Figure 9, which shows a typical two-dimensional wall pier interaction diagram. The forces obtained from a given design load combination are P_u and $M3_u$. The point L, defined by (P_u, $M3_u$), is placed on the interaction diagram as shown in the figure. If the point lies within the interaction curve, the wall pier capacity is adequate. If the point lies outside of the interaction curve, the wall pier is overstressed.

As a measure of the stress condition in the wall pier, the program calculates a stress ratio. The ratio is achieved by plotting the point L and determining the location of point C. The point C is defined as the point where the line OL (extended outward if needed) intersects the interaction curve. The demand/capacity ratio, D/C, is given by D/C = OL / OC where OL is the "distance" from point O (the origin) to point L and OC is the "distance" from point O to point C. Note the following about the demand/capacity ratio:

- If OL = OC (or D/C = 1), the point (P_u, $M3_u$) lies on the interaction curve and the wall pier is stressed to capacity.

- If OL < OC (or D/C < 1), the point (P_u, $M3_u$) lies within the interaction curve and the wall pier capacity is adequate.

- If OL > OC (or D/C > 1), the point (P_u, $M3_u$) lies outside of the interaction curve and the wall pier is overstressed.

The wall pier demand/capacity ratio is a factor that gives an indication of the stress condition of the wall with respect to the capacity of the wall.

The demand/capacity ratio for a three-dimensional wall pier is determined in a similar manner to that described here for two-dimensional piers.

Designing a General Reinforcing Pier Section

When you specify that a General Reinforcing pier section is to be designed, the program creates a series of interaction surfaces for the pier based on the following items:

1. The size of the pier as specified in Section Designer.

2. The location of the reinforcing specified in Section Designer.

3. The size of each reinforcing bar specified in Section Designer *relative* to the size of the other bars.

The interaction surfaces are developed for eight different ratios of reinforcing steel area to pier area. The pier area is held constant and the rebar area is modified to obtain these different ratios; however, the *relative* size (area) of each rebar compared to the other bars is always kept constant.

The smallest of the eight reinforcing ratios used is that specified in the shear wall design preferences as Section Design IP-Min. Similarly, the largest of the eight reinforcing ratios used is that specified in the shear wall design preferences as Section Design IP-Max.

The eight reinforcing ratios used are the maximum and the minimum ratios plus six more ratios. The spacing between the reinforcing ratios is calculated as an increasing arithmetic series in which the space between the first two ratios is equal to one-third of the space between the last two ratios.

Table 1 illustrates the spacing, both in general terms and for a specific example, when the minimum reinforcing ratio, IPmin, is 0.0025 and the maximum, IPmax, is 0.02.

Table 1 The Eight Reinforcing Ratios Used by the Program

Curve	Ratio	Example
1	IPmin	0.0025
2	$\text{IPmin} + \frac{\text{IPmax} - \text{IPmin}}{14}$	0.0038
3	$\text{IPmin} + \frac{7}{3}\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0054
4	$\text{IPmin} + 4\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0075
5	$\text{IPmin} + 6\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0100
6	$\text{IPmin} + \frac{25}{3}\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0129
7	$\text{IPmin} + 11\left(\frac{\text{IPmax} - \text{IPmin}}{14}\right)$	0.0163
8	IPmax	0.0200

After the eight reinforcing ratios have been determined, the program develops interaction surfaces for all eight of the ratios using the process described earlier in this Technical Note in the section entitled "Checking a Section Designer Pier Section."

Next, for a given design load combination, the program generates a demand/capacity ratio associated with each of the eight interaction surfaces. The program then uses linear interpolation between the eight interaction surfaces to determine the reinforcing ratio that gives an demand/capacity ratio of 1 (actually the program uses 0.99 instead of 1). This process is repeated for all design load combinations and the largest required reinforcing ratio is reported.

Design of a Uniform Reinforcing pier section is similar to that described herein for the General Reinforcing section.

Technical Note 27
Wall Pier Shear Design

This Technical Note describes how the program designs each leg of concrete wall piers for shear using ACI318-99. Note that in this program you cannot specify shear reinforcing and then have the program check it. The program only designs the pier for shear and reports how much shear reinforcing is required. The shear design is performed at stations at the top and bottom of the pier.

General

The wall pier shear reinforcing is designed for each of the design load combinations. The following steps are involved in designing the shear reinforcing for a particular wall pier section for a particular design loading combination.

1. Determine the factored forces P_u, M_u and V_u that are acting on the wall pier section. Note that P_u and M_u are required for the calculation of V_c.

2. Determine the shear force, V_c, that can be carried by the concrete.

3. Determine the required shear reinforcing to carry the balance of the shear force.

Step 1 needs no further explanation. The following two sections describe in detail the algorithms associated with the Steps 2 and 3.

Note:

The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this Technical Note is a shear strength reduction factor that applies to lightweight concrete. It is equal to 1 for normal weight concrete. This factor is specified in the concrete material properties.

Determine the Concrete Shear Capacity

Given the design force set P_u, M_u and V_u acting on a wall pier section, the shear force carried by the concrete, V_c, is calculated using Equations 1 and 2.

$$V_c = 3.3R_{LW}\sqrt{f'_c}\; t_p\left(0.8L_p\right) - \frac{P_u\left(0.8L_p\right)}{4L_p} \qquad \text{Eqn. 1}$$

where V_c may not be greater than

$$V_c = \left[0.6R_{LW}\sqrt{f'_c} + \frac{L_p\left(1.25R_{LW}\sqrt{f'_c} - 0.2\frac{P_u}{L_p t_p}\right)}{\text{Abs}\left(\frac{M_u}{V_u}\right) - \frac{L_p}{2}}\right] t_p\left(0.8L_p\right) \qquad \text{Eqn. 2}$$

Equation 2 doesn't apply if $\text{Abs}\left(\frac{M_u}{V_u}\right) - \frac{L_p}{2}$ is negative or zero, or if V_u is zero.

If the tension is large enough that Equation 1 or Equation 2 results in a negative number, V_c is set to zero.

Note that these equations are identical to Equations 11-31 and 11-32 in Chapter 11, Section 11.10.6 of the ACI318-99 with the ACI dimension "d" set equal to 0.8*L_p. The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this Technical Note is a shear strength reduction factor that applies to lightweight concrete. It is equal to 1 for normal weight concrete. This factor is specified in the concrete material properties.

Recall that in the program tension is positive; thus, the negative sign on the second term in Equation 1 is consistent with Equation 11-31 in ACI318-99. Similarly, the negative sign on the second term in the parenthesis of Equation 2 is consistent with Equation 11-32 in ACI318-99.

Note:

You can set the output units for the distributed shear reinforcing in the shear wall design preferences.

Determine the Required Shear Reinforcing

Seismic and Nonseismic Piers

Given V_u and V_c, Equation 3 provides the required shear reinforcing in area per unit length (e.g., square inches per inch) for both seismic and nonseismic wall piers (as indicated by the "Design is Seismic" item in the pier design overwrites). Note that additional requirements for seismic piers are provided later in this section.

$$A_v = \frac{\dfrac{Abs(V_u)}{\phi} - V_c}{f_{ys}\ (0.8L_p)} \qquad \text{Eqn. 3}$$

where,

$V_n = \dfrac{Abs\ (V_u)}{\phi}$ must not exceed $10R_{LW}\sqrt{f'_c}\ t_p\left(0.8L_p\right)$ per ACI318-99 Section 11.10.3.

In Equation 3, the term ϕ is equal to ϕ_{vns} for nonseismic piers and to ϕ_{vs} for seismic piers. The ϕ (phi) factors are specified in the shear wall design preferences.

Additional Requirements for Seismic Piers

For shear design of seismic wall piers, the following additional requirements are also checked.

The nominal shear strength of the wall pier is limited to:

$$V_n = \left(2R_{LW}\sqrt{f'_c} + \frac{A_v}{t_p} f_{ys}\right) L_p t_p \qquad \text{Eqn. 4}$$

where,

$V_n = \dfrac{Abs\ (V_u)}{\phi_{vs}}$ must not exceed $8R_{LW}\sqrt{f'_c}\ t_p L_p$ per ACI318-99 Section 21.6.4.4.

A_v is the horizontal shear reinforcing per unit vertical length (height) of the wall pier. Equation 4 is based on Equation 21-7 in Section 21.6.4.1 of ACI318-99. Since $V_u = \phi_{vs}V_n$, A_v can be calculated as shown in Equation 5.

$$A_v = \frac{\dfrac{Abs\,(V_u)}{\phi_{vs}} - 2R_{LW}\sqrt{f'_c}\;L_p t_p}{f_{ys}L_p} \qquad \text{Eqn. 5}$$

Note that the maximum wall pier nominal shear force is limited by the program to $8R_{LW}\sqrt{f'_c}\;t_pL_p$ not $10R_{LW}\sqrt{f'_c}\;t_pL_p$.

Technical Note 28
Spandrel Flexural Design

This Technical Note describes how the program designs concrete shear wall spandrels for flexure using the ACI318-99 requirements. This program allows consideration of rectangular sections and T-beam sections for shear wall spandrels. Note that the program designs spandrels at stations located at the ends of the spandrel. No design is performed at the center (mid-length) of the spandrel.

General

The spandrel flexural reinforcing is designed for each of the design load combinations. The required area of reinforcing for flexure is calculated and reported only at the ends of the spandrel beam.

In this program, wall spandrels are designed for major direction flexure and shear only. Effects caused by any axial forces, minor direction bending, torsion or minor direction shear that may exist in the spandrels must be investigated by the user independent of the program.

The following steps are involved in designing the flexural reinforcing for a particular wall spandrel section for a particular design loading combination at a particular station.

- Determine the maximum factored moment M_u.
- Determine the required flexural reinforcing.

These steps are described in the following sections.

Determine the Maximum Factored Moments

In the design of flexural reinforcing for spandrels, the factored moments for each design load combination at a particular beam station are first obtained.

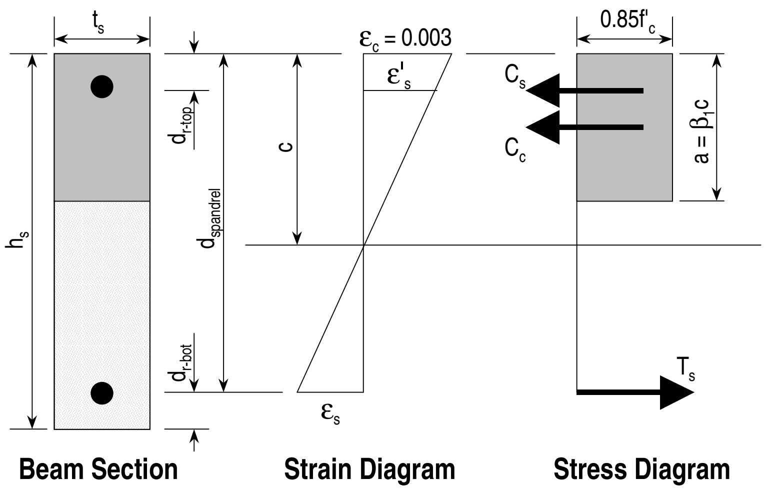


Figure 1: Rectangular spandrel beam design, positive moment

The beam section is then designed for the maximum positive and the maximum negative factored moments obtained from all of the design load combinations.

Determine the Required Flexural Reinforcing

In this program, negative beam moments produce top steel. In such cases, the beam is always designed as a rectangular section.

In this program, positive beam moments produce bottom steel. In such cases, the beam may be designed as a rectangular section, or as a T-beam section. You indicate that a spandrel is to be designed as a T-beam by providing appropriate slab width and depth dimensions in the spandrel design overwrites.

The flexural design procedure is based on a simplified rectangular stress block, as shown in Figure 1. It is assumed that the compression carried by the concrete is less than or equal to 0.75 times that which can be carried at the balanced condition. When the applied moment exceeds the moment capacity at 0.75 times the balanced condition, the program calculates an area of compression reinforcement assuming that the additional moment is carried by compression reinforcing and additional tension reinforcing.

The procedure used by the program for both rectangular and T-beam sections is given below.

Rectangular Beam Flexural Reinforcing

Refer to Figure 1. For a rectangular beam, the factored moment, M_u, is resisted by a couple between the concrete in compression and the tension in reinforcing steel. This is expressed in Equation 1.

$$M_u = C_c\left(d_{spandrel} - \frac{a}{2}\right) \qquad \text{Eqn. 1}$$

where $C_c = 0.85\phi_b f'_c a t_s$ and $d_{spandrel}$ is equal to h_s - $d_{r\text{-}bot}$ for positive bending and h_s - $d_{r\text{-}top}$ for negative bending.

Equation 1 can be solved for the depth of the compression block, a, yielding Equation 2.

$$a = d_{spandrel} - \sqrt{d^2_{spandrel} - \frac{2M_u}{0.85 f'_c\ \phi_b\ t_s}} \qquad \text{Eqn. 2}$$

The program uses Equation 2 to determine the depth of the compression block, a.

The depth of the compression block, a, is compared with $0.75\beta_1 c_b$, where

$$\beta_1 = 0.85 - \frac{0.05\left(f'_c - 4{,}000\right)}{1{,}000} \qquad \text{Eqn. 3}$$

with a maximum of 0.85 and a minimum of 0.65. c_b, the distance from the extreme compression fiber to the neutral axis for balanced strain conditions, is given by Equation 4.

$$c_b = \frac{87000}{87000 + f_y}\, d_{spandrel} \qquad \text{Eqn. 4}$$

Note:

If the required tension reinforcing exceeds 75% of the balanced reinforcing, the program provides compression steel to help resist the applied moment.

Tension Reinforcing Only Required

If $a \le 0.75\beta_1 c_b$, no compression reinforcing is required and the program calculates the area of tension reinforcing using Equation 5.

$$A_s = \frac{M_u}{\phi_b f_y \left(d_{spandrel} - \frac{a}{2} \right)} \qquad \text{Eqn. 5}$$

The steel is placed at the bottom for positive moment and in the top for negative moment.

Note:

The program reports the ratio of top and bottom steel required in the web area. When compression steel is required, these ratios may be large because there is no limit on them. However, the program reports an overstress when the ratio exceeds 4%.

Tension and Compression Reinforcing Required

If $a > 0.75\beta_1 c_b$, compression reinforcing is required and the program calculates required compression and tension reinforcing as follows.

The depth of the concrete compression block, a, is set equal to $a_b = 0.75\beta_1 c_b$. The compressive force developed in the concrete alone is given by Equation 6.

$$C_c = 0.85 f'_c a_b t_s \qquad \text{Eqn. 6}$$

The moment resisted by the couple between the concrete in compression and the tension steel, M_{uc}, is given by Equation 7.

$$M_{uc} = \phi_b C_c \left(d_{spandrel} - \frac{a_b}{2} \right) \qquad \text{Eqn. 7}$$

Therefore, the additional moment to be resisted by the couple between the compression steel and the additional tension steel, M_{us}, is given by

$$M_{us} = M_u - M_{uc} \qquad \text{Eqn. 8}$$

The force carried by the compression steel, C_s, is given by Equation 9.

$$C_s = \frac{M_{us}}{d_{spandrel} - d_r} \qquad \text{Eqn. 9}$$

Referring to Figure 1, the strain in the compression steel, ε'_s, is given by Equation 10.

$$\varepsilon_s^{'} = \frac{0.003\left(c - d_r\right)}{c} \qquad \text{Eqn. 10}$$

The stress in the compression steel, f'_s, is given by Equation 11.

$$f_s^{'} = E_s \varepsilon_s^{'} = \frac{0.003 E_s \left(c - d_r\right)}{c} \qquad \text{Eqn. 11}$$

The term d_r in Equations 9, 10 and 11 is equal to $d_{r\text{-}top}$ for positive bending and equal to $d_{r\text{-}bot}$ for negative bending. In Equations 10 and 11, the term c is equal to a_b/β_1.

The total required area of compression steel, A'_s; is calculated using Equation 12.

$$A_s^{'} = \frac{C_s}{\phi_b (f_s^{'} - 0.85 f_c^{'})} \qquad \text{Eqn. 12}$$

The required area of tension steel for balancing the compression in the concrete web, A_{sw}, is:

$$A_{sw} = \frac{M_{uc}}{\phi_b f_y \left(d_{spandrel} - \frac{a_b}{2}\right)} \qquad \text{Eqn. 13}$$

Note that Equation 13 is similar to Equation 5 that is used when only tension reinforcing is required.

The required area of tension steel for balancing the compression steel, A_{sc}, is:

$$A_{sc} = \frac{M_{us}}{\phi_b f_y \left(d_{spandrel} - d_r\right)} \qquad \text{Eqn. 14}$$

In Equations 13 and 14, $d_{spandrel}$ is equal to h_s - $d_{r\text{-}bot}$ for positive bending and h_s - $d_{r\text{-}top}$ for negative bending. In Equation 14, d_r is equal to $d_{r\text{-}top}$ for positive bending and $d_{r\text{-}bot}$ for negative bending.

The total tension reinforcement A_s is given by Equation 15.

$$A_s = A_{sw} + A_{sc} \qquad \text{Eqn. 15}$$

where A_{sw} and A_{sc} are determined from Equations 13 and 14, respectively.

Thus, the total tension reinforcement, A_s, is given by Equation 15 and the total compression reinforcement, A'_s, is given by Equation 12. A_s is to be placed at the bottom of the beam and A'_s at the top for positive bending and vice versa for negative bending.

T-Beam Flexural Reinforcing

T-beam action is only considered effective for positive moment. When designing T-beams for negative moment (i.e., designing top steel), the calculation of required steel is as described in the previous section for rectangular sections. No T-beam data is used in this design. The width of the beam is taken equal to the width of the web.

For positive moment, the depth of the compression block, a, is initially determined using Equation 2. The method for calculating the required reinforcing steel relates the compression block depth, a, calculated using Equation 2, to the depth of the T-beam flange, d_s. See Figure 2.

- **If $a \le d_s$**, the subsequent calculations for the reinforcing steel are exactly the same as previously defined for rectangular section design. However, in that case, the width of the compression block is taken to be equal to the width of the compression flange, b_s. Compression reinforcement is provided when the dimension "a" exceeds $0.75\beta_1 c_b$, where β_1 and c_b are given by Equations 3 and 4, respectively.

- **If $a > d_s$**, the subsequent calculations for the required area of reinforcing steel are performed in two parts. First, the tension steel required to balance the compressive force in the flange is determined, and second, the tension steel required to balance the compressive force in the web is determined. If necessary, compression steel is added to help resist the design moment.

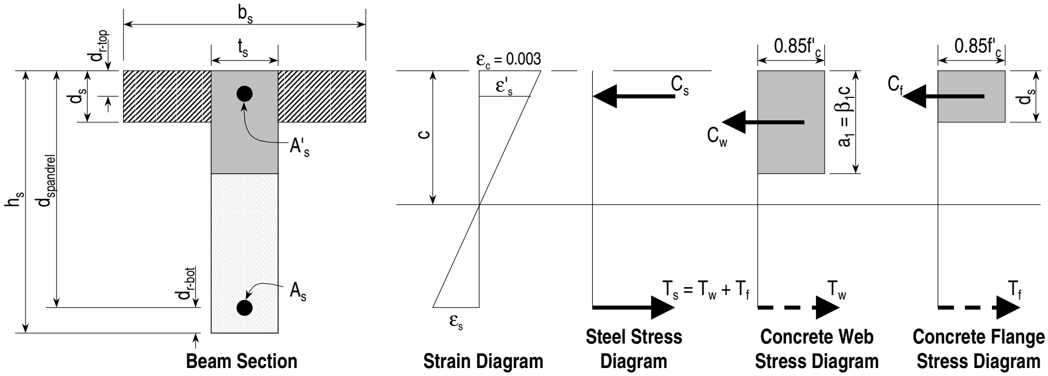


Figure 2: Design of a Wall Spandrel with a T-Beam Section, Positive Moment

The remainder of this section describes in detail the design process used by the program for T-beam spandrels when $a > d_s$.

Refer to Figure 2. The compression force in the protruding portion of the flange, C_f, is given by Equation 16. The protruding portion of the flange is shown cross-hatched.

$$C_f = 0.85f'_c\,(b_s - t_s)d_s \qquad \text{Eqn. 16}$$

Note:

T-beam action is only considered for positive moment.

The required area of tension steel for balancing the compression force in the concrete flange, A_{sf}, is:

$$A_{sf} = \frac{C_f}{f_y} \qquad \text{Eqn. 17}$$

The portion of the total moment, M_u, that is resisted by the flange, M_{uf}, is given by Equation 18.

$$M_{uf} = \phi_b C_f \left(d_{spandrel} - \frac{d_s}{2} \right) \qquad \text{Eqn. 18}$$

Therefore the balance of the moment to be carried by the web, M_{uw}, is given by

$$M_{uw} = M_u - M_{uf} \qquad \text{Eqn. 19}$$

The web is a rectangular section of width t_s and depth h_s for which the design depth of the compression block, a_1, is recalculated as:

$$a_1 = d_{spandrel} - \sqrt{d_{spandrel}^2 - \frac{2M_{uw}}{0.85f'_c\,\phi_b\,t_s}} \qquad \text{Eqn. 20}$$

Tension Reinforcing Only Required

If $a_1 \le 0.75\beta_1 c_b$, where β_1 and c_b are calculated from Equations 3 and 4, respectively, no compression reinforcing is required and the program calculates the area of tension steel for balancing the compression force in the concrete web, A_{sw}, using Equation 21.

$$A_{sw} = \frac{M_{uw}}{\phi_b f_y\left(d_{spandrel} - \frac{a_1}{2}\right)} \qquad \text{Eqn. 21}$$

The total tension reinforcement A_s is given by Equation 22.

$$A_s = A_{sf} + A_{sw} \qquad \text{Eqn. 22}$$

The total tension reinforcement, A_s, given by Equation 22 is to be placed at the bottom of the beam for positive bending.

Tension and Compression Reinforcing Required

If $a_1 > 0.75\beta_1 c_b$, where a_1 is calculated using Equation 20 and β_1 and c_b are calculated from Equations 3 and 4, respectively, compression reinforcing is required. In that case, the required reinforcing is computed as follows.

The depth of the concrete compression block, a, is set equal to $a_b = 0.75\beta_1 c_b$. The compressive force developed in the web concrete alone is given by Equation 23.

$$C_w = 0.85f'_c a_b t_s \qquad \text{Eqn. 23}$$

The moment resisted by the couple between the concrete web in compression and the tension steel, M_{uc}, is given by Equation 24.

$$M_{uc} = \phi_b C_w \left(d_{spandrel} - \frac{a_b}{2} \right) \quad \text{Eqn. 24}$$

Therefore, the additional moment to be resisted by the couple between the compression steel and the tension steel, M_{us}, is given by:

$$M_{us} = M_{uw} - M_{uc} \quad \text{Eqn. 25}$$

Referring to Figure 2, the force carried by the compression steel, C_s, is given by Equation 26.

$$C_s = \frac{M_{us}}{d_{spandrel} - d_{r\text{-}top}} \quad \text{Eqn. 26}$$

The strain in the compression steel, ε'_s, is given by Equation 27.

$$\varepsilon'_s = \frac{0.003\left(c - d_{r\text{-}top}\right)}{c} \quad \text{Eqn. 27}$$

The stress in the compression steel, f'_s, is given by Equation 28.

$$f'_s = E_s \varepsilon'_s = \frac{0.003 E_s \left(c - d_{r\text{-}top}\right)}{c} \quad \text{Eqn. 28}$$

In Equations 27 and 28 the term c is equal to a_b/β_1.

The required area of compression steel, A'_s; is calculated using Equation 29.

$$A'_s = \frac{C_s}{\phi_b f'_s} \quad \text{Eqn. 29}$$

The required area of tension steel for balancing the compression in the concrete web, A_{sw}, is:

$$A_{sw} = \frac{M_{uc}}{\phi_b f_y \left(d_{spandrel} - \frac{a_b}{2} \right)} \quad \text{Eqn. 30}$$

The required area of tension steel for balancing the compression steel, A_{sc}, is:

$$A_{sc} = \frac{M_{us}}{\phi_b f_y \left(d_{spandrel} - d_{r\text{-}top}\right)} \qquad \text{Eqn. 31}$$

The total tension reinforcement A_s is given by Equation 15.

$$A_s = A_{sf} + A_{sw} + A_{sc} \qquad \text{Eqn. 32}$$

where A_{sf}, A_{sw} and A_{sc} are determined from Equations 17, 30 and 31, respectively.

The total tension reinforcement, A_s, is given by Equation 32 and the total compression reinforcement, A'_s, is given by Equation 29. A_s is to be placed at the bottom of the beam and A'_s at the top of the beam.

ETABS®

SHEAR WALL DESIGN ACI318-99

Technical Note 29
Spandrel Shear Design

This Technical Note describes how the program designs concrete wall spandrels for shear using ACI318-99. Note that in this program you cannot specify shear reinforcing and then have the program check it. The program only designs the spandrel for shear and reports how much shear reinforcing is required.

The program allows consideration of rectangular sections and T-beam sections for wall spandrels. The shear design for both of these types of spandrel sections is identical.

General

The wall spandrel shear reinforcing is designed for each of the design load combinations. The required area of reinforcing for vertical shear is only calculated at the ends of the spandrel beam.

In this program, wall spandrels are designed for major direction flexure and shear forces only. Effects caused by any axial forces, minor direction bending, torsion or minor direction shear that may exist in the spandrels must be investigated by the user independent of the program.

The following steps are involved in designing the shear reinforcing for a particular wall spandrel section for a particular design loading combination at a particular station.

1. Determine the factored shear force V_u.

2. Determine the shear force, V_c, that can be carried by the concrete.

3. Determine the required shear reinforcing to carry the balance of the shear force.

Note:

You can specify in the overwrites that V_c is to be ignored (set to zero) for spandrel shear calculations.

Step 1 needs no further explanation. The following two sections describe in detail the algorithms associated with Steps 2 and 3.

Determine the Concrete Shear Capacity

The shear force carried by the concrete, V_c, is calculated using Equation 1.

$$V_c = 2R_{LW}\sqrt{f'_c}\, t_s d_{spandrel} \qquad \text{Eqn. 1}$$

Equation 1 is based on Equation 11-3 in Chapter 11, Section 11.3.1.1 of ACI318-99.

Note that there is an overwrite available that allows you to ignore the concrete contribution to the shear strength of the spandrel. If this overwrite is activated, the program sets V_c to zero for the spandrel.

The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this Technical Note is a shear strength reduction factor that applies to lightweight concrete. It is equal to 1 for normal weight concrete. This factor is specified in the concrete material properties.

Note:

The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this Technical Note is a shear strength reduction factor that applies to lightweight concrete. It is equal to 1 for normal weight concrete. This factor is specified in the concrete material properties.

Determine the Required Shear Reinforcing

One of the terms used in calculating the spandrel shear reinforcing is $d_{spandrel}$, which is the distance from the extreme compression fiber to the centroid of the tension steel. For shear design, the program takes $d_{spandrel}$ to be equal to the smaller of h_s-$d_{r\text{-}top}$ and h_s-$d_{r\text{-}bot}$.

Seismic and Nonseismic Spandrels

In this entire subsection the term ϕ is equal to ϕ_{vns} for nonseismic spandrels and to ϕ_{vs} for seismic spandrels.

Given V_u and V_c, the required force to be carried by the shear reinforcing, V_s, is calculated using Equation 2.

$$V_s = V_n - V_c = \frac{V_u}{\phi} - V_c \qquad \text{Eqn. 2}$$

If V_s as calculated in Equation 2 exceeds $8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}$, a failure condition is reported per ACI318-99 Section 11.5.6.9.

Given V_s, Equation 3 initially calculates the required vertical shear reinforcing in area per unit length (e.g., square inches per foot) for both seismic and nonseismic wall spandrels (as indicated in the preferences). Note that additional requirements that are checked for both seismic and nonseismic wall spandrels are given following Equation 3.

$$A_v = \frac{V_n - V_c}{f_{ys} d_{spandrel}} = \frac{V_s}{f_{ys} d_{spandrel}} \qquad \text{Eqn. 3}$$

Note:

You can set the output units for the distributed shear reinforcing in the shear wall design preferences.

The following additional checks are also performed for both seismic and nonseismic spandrels.

- When $\frac{L_s}{d_{spandrel}} > 5$, the program verifies:

  $$V_s \le 8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}, \qquad \text{Eqn. 4a}$$

  otherwise a failure condition is declared per Section 11.5.6.9 of ACI318-99.

- ✓ When $\frac{L_s}{d_{spandrel}} > 5$ and $\frac{V_u}{\phi} > 0.5V_c$, the minimum areas of vertical and horizontal shear reinforcing in the spandrel are:

$$A_{v\text{-}min} = \frac{50t_s}{f_{ys}} \quad \text{Eqn. 4b}$$

$$A_{h\text{-}min} = 0 \quad \text{Eqn. 4c}$$

Equation 4b is based on Equation 11-13 in Section 11.5.5.3 of ACI318-99.

- ✓ When $\frac{L_s}{d_{spandrel}} > 5$ and $\frac{V_u}{\phi} \le 0.5V_c$, the minimum areas of vertical and horizontal shear reinforcing in the spandrel are:

$$A_{v\text{-}min} = A_{h\text{-}min} = 0 \quad \text{Eqn. 4d}$$

Note:

When calculating the $L_s/d_{spandrel}$ term, the program always uses the smallest value of $d_{spandrel}$ that is applicable to the spandrel.

- When $2 \le \frac{L_s}{d_{spandrel}} \le 5$, the program verifies:

$$V_n = \frac{V_u}{\phi} \le \frac{2}{3}\left(10 + \frac{L_s}{d_{spandrel}}\right) R_{LW}\sqrt{f'_c}\, t_s d_{spandrel} \quad \text{Eqn. 4e}$$

otherwise a failure condition is declared per Equation 11-27 in Section 11.8.4 of ACI318-99. For this condition, the minimum areas of horizontal and vertical shear reinforcing in the spandrel are:

$$A_{v\text{-}min} = 0.0015t_s \quad \text{Eqn. 4f}$$

$$A_{h\text{-}min} = 0.0025t_s \quad \text{Eqn. 4g}$$

- When $\frac{L_s}{d_{spandrel}} < 2$, the program verifies:

$$V_n = \frac{V_u}{\phi} \le 8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}\,, \qquad \text{Eqn. 4h}$$

otherwise a failure condition is declared per Section 11.8.4 of ACI318-99. For this condition, the minimum areas of horizontal and vertical shear reinforcing in the spandrel are:

$$A_{v\text{-}min} = 0.0015t_s \qquad \text{Eqn. 4i}$$

$$A_{h\text{-}min} = 0.0025t_s \qquad \text{Eqn. 4j}$$

Equations 4f and 4i are based on Section 11.8.9 of ACI318-99. Equations 4g and 4j are based on Section 11.8.10 of ACI318-99.

Note that the check in Equation 4a is based on V_s, whereas the checks in Equations 4e and 4h are based on V_n.

Note:

For nonseismic spandrels, A_{vd} is reported as zero.

Seismic Spandrels Only

For seismic spandrels only, in addition to the requirements of the previous subsection, an area of diagonal shear reinforcement in coupling beams is also calculated when $\frac{L_s}{d_{spandrel}} < 4$ using Equation 5.

$$A_{vd} = \frac{V_u}{2\,(0.85)\,f_{ys}\sin\alpha}\,, \qquad \text{Eqn. 5}$$

where,

$$\sin\alpha = \frac{0.8h_s}{\sqrt{L_s^2 + (0.8h_s)^2}}\,,$$

where h_s is the height of the spandrel and L_s is the length of the spandrel.

In the output, the program reports the diagonal shear reinforcing as either required or not required (i.e., optional). The diagonal shear reinforcing is reported as required when $V_u > 4\sqrt{f'_c}\,db_{spandrel}$.

SHEAR WALL DESIGN ACI318-99

Technical Note 30
Wall Pier Boundary Elements

This Technical Note describes how the program considers the boundary element requirements for each leg of concrete wall piers using ACI318-99. The program uses an approach based on the requirements of Section 21.6.6 in ACI318-99.

Note that the boundary element requirements are considered separately for each design load case that includes seismic load.

Note:

The program considers only the requirements of Section 21.6.6.2 of ACI318-99 in determining boundary element requirements. Section 21.6.6.3 is not considered by the program.

Details of Check for Boundary Element Requirements

The following information is available for the boundary element check:

- The design forces P_u, V_u and M_u for the pier section.
- The length of the wall pier, L_p, the gross area of the pier, A_g, and the net area of the pier, A_{cv}. The net area of the pier is the area bounded by the web thickness, t_p, and the length of the pier. Refer to Figure 1 in Shear Wall Design Technical Note 6 Wall Pier Design Sections for an illustration of the dimensions L_p and t_p.
- The area of steel in the pier, A_s. This area of steel is either calculated by the program or it is provided by the user.
- The material properties of the pier, f'_c and f_y.
- The symmetry of the wall pier (i.e., is the left side of the pier the same as the right side of the pier). Only the geometry of the pier is considered, not the reinforcing, when determining if the pier is symmetrical. Figure 1 shows some examples of symmetrical and unsymmetrical wall piers. Note

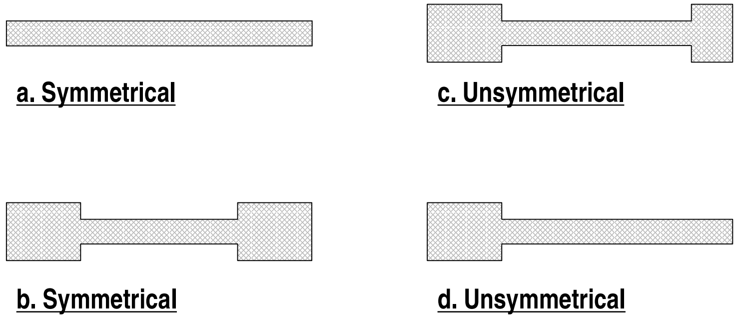


Figure 1 Example Plan Views of Symmetrical and Unsymmetrical Wall Piers

that a pier defined in Section Designer is assumed to be unsymmetrical unless it is made up of a single rectangular shape.

Using this information, the program calculates the value of P_O, which is the nominal axial load strength of the wall using Equation 1.

$$P_O = 0.85f'_c\,(A_g - A_s) + f_yA_s \qquad \text{Eqn. 1}$$

Note:

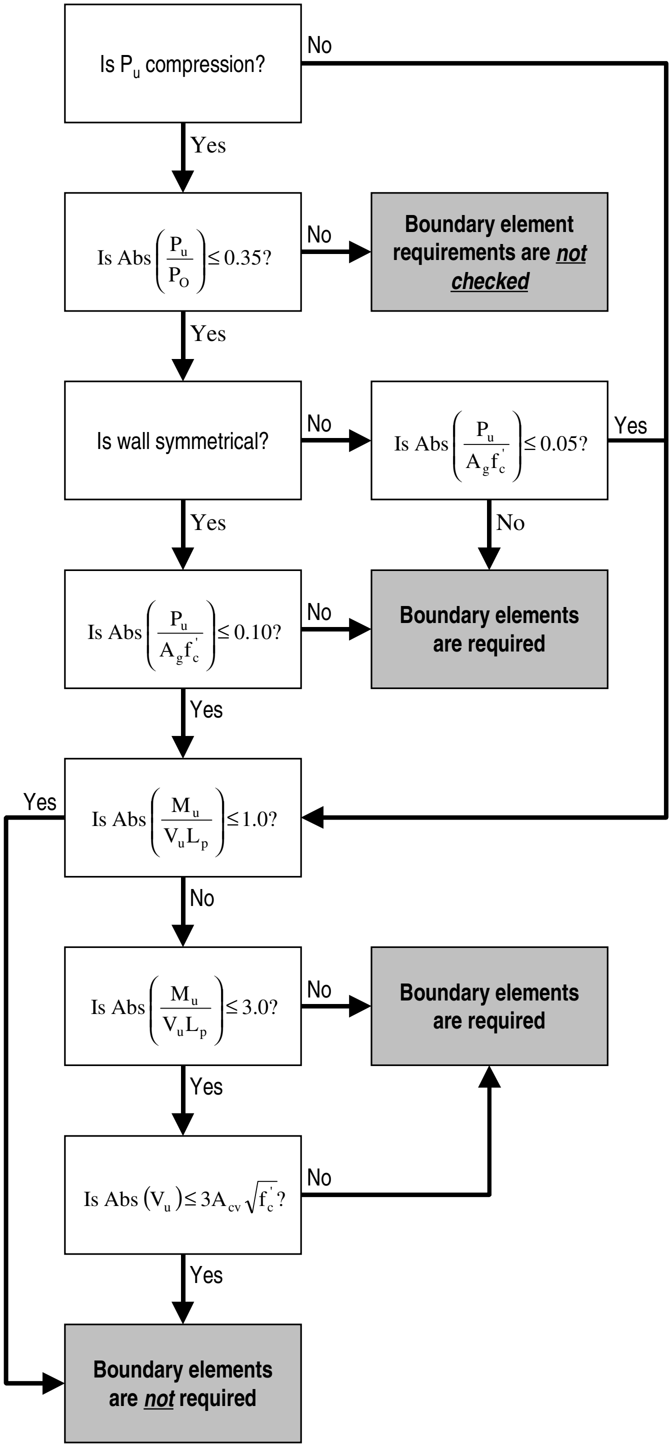
For simplified design only, if there is a flexural failure in any design load combination, the program sets A_s in Equation 1 to zero for all design load combinations considered for the pier.

After the value of P_O is known, the program calculates four quantities that are used to determine the boundary zone requirements. These quantities are:

- $\dfrac{P_u}{P_O}$
- $\dfrac{M_u}{V_uL_p}$
- $\dfrac{P_u}{A_g f'_c}$
- $3A_{cv}\sqrt{f'_c}$

The flowchart in Figure 2 illustrates the process the program uses to determine if boundary elements are required. Note that if P_u exceeds 0.35 P_O, the boundary element requirements are not checked.

Figure 2
Flowchart of the Process the Program Uses to Determine if Boundary Elements Are Required



If boundary elements are required, the program calculates the minimum required length of the boundary zone at each end of the wall, L_{BZ}, according to the requirements of Section 21.6.6 in ACI318-99. The code requires that L_{BZ} vary linearly from $0.25L_p$ to $0.15L_p$ for P_u, varying from $0.35P_O$ to $0.15P_O$, and that L_{BZ} shall not be less than $0.15L_p$. Based on these requirements, the program calculates L_{BZ} using either Equation 2a or 2b, depending on whether P_u is compression or tension.

When P_u is compression:

$$L_{BZ} = \left[\text{Abs}\left(\frac{P_u}{2P_O} \right) + 0.075 \right] L_p \geq 0.15L_p \qquad \text{Eqn. 2a}$$

When P_u is tension:

$$L_{BZ} = 0.15L_p \qquad \text{Eqn. 2b}$$

Figure 3 illustrates the boundary zone length L_{BZ}.

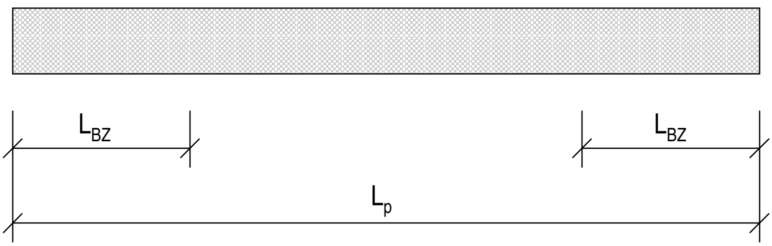


Figure 3: Illustration of Boundary Zone Length, L_{BZ}

Example

Figure 4 shows an example wall pier. The pier is 12.5 feet long. It is reinforced with #5 bars at 12 inches on center on each face. Refer to the figure for properties and forces.

Note:

Boundary element requirements are considered by the program for two- and three-dimensional wall piers

The calculations follow:

P_u = 1,000 kips (given)

L_p = 12.5 feet = 150 inches (given)

A_g = 12.5 ft * 1 ft = 12.5 ft^2 = 1,800 in^2

A_s = 13 bars * 2 faces * 0.31 in^2 = 8.06 in^2

f'_c = 4 ksi (given)

f_y = 60 ksi (given)

The pier is symmetrical. (given)

$P_O = 0.85f'_c\,(A_g - A_s) + f_yA_s$

P_O = 0.85 * 4 (1,800 - 8.06) + 60 * 8.06 = 6,576 kips

$$\frac{P_u}{P_O} = \frac{1{,}000}{6{,}576} = 0.152 < 0.35 \quad \underline{\textbf{OK}}$$

$$\frac{P_u}{A_g f'_c} = \frac{1{,}000}{1{,}800 * 4} = 0.139 > 0.1 \quad \underline{\textbf{NG}}$$

Therefore boundary elements are required.

$$L_{BZ} = \left(\frac{1{,}000}{2 * 6{,}576} + 0.075\right) * 150 = 22.7 \text{ inches}$$

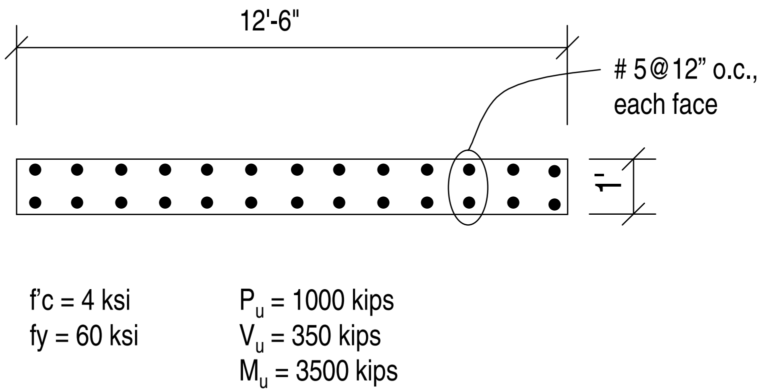


Figure 4: Wall Pier Example Calculations

Displaying the pier boundary zone data provides either the required boundary zone length, or "NC" (short for Not Checked) if boundary zone requirements are not checked because $P_u/P_o > 0.35$, or "NN" (short for Not Needed) if boundary zones are not required.

SHEAR WALL DESIGN ACI 318-99

Technical Note 31
Input Data

General

This Technical Note describes the shear wall input data that can be printed to a printer or to a text file when you click the **File menu > Print Tables > Shear Wall Design** command.

Using the Print Shear Wall Design Tables Form

To print Shear Wall design input data directly to a printer, use the **File menu > Print Tables > Shear Wall Design** command and click the Input Summary check box on the Print Shear Wall Design Tables form next to the desired type(s) of data. Click the **OK** button to send the print to your printer. Click the **Cancel** button rather than the **OK** button to cancel the print.

Use the **File menu > Print Setup** command and the **Setup>>** button to change printers, if necessary.

To print shear wall design input data to a file, use the **File menu > Print Tables > Shear Wall Design** command and click the Print to File check box on the Print Shear Wall Design Tables form. Click the **Filename** button to change the path or filename. Use the appropriate file extension for the desired format (e.g., .txt, .xls, .doc). Click the **Save** buttons on the Open File for Printing Tables form and the Print Shear Wall Design Tables form to complete the request.

Note:

The **File menu > Display Input/Output Text Files** command is useful for displaying output that is printed to a text file.

The Append check box allows you to add data to an existing file. The path and filename of the current file is displayed in the box near the bottom of the Print Shear Wall Design Tables form. Data will be added to this file. Or use the

Filename button to locate another file, and when the Open File for Printing Tables caution box appears, click Yes to replace the existing file.

If you select a specific shear wall(s) before using the **File menu > Print Tables > Shear Wall Design** command, the Selection Only check box will be checked. The print will be for the selected wall(s) only. If you uncheck the Selection Only check box, the print will be for all shear walls.

Summary Input Data

Summary input data are described in Shear Wall Design Technical Note 4 Input Data.

Design Preferences Input Data

The output for the Shear Wall design preferences is provided in a series of tables. The tables correspond to the tabs in the Preferences form. You can click the **Options menu > Preferences > Shear Wall Design** command to access the Shear Wall preferences.

Note:

The Shear Wall preferences are described in ACI318-99 Shear Wall Design Technical Note 23 Preferences.

Recall that the Shear Wall preferences apply to all beams designed using the Shear Wall Design postprocessor. A few of the preference items can be overwritten on a beam-by-beam basis in the Shear Wall overwrites. Those preferences items that can be overwritten are mentioned in this documentation. You can select one or more beams and then click the **Design menu > Shear Wall Design > View/Revise Overwrites** command to access the Shear Wall overwrites.

Table 1 of Shear Wall Design Technical Note 4 Input Data identifies the Shear Wall Design Preferences Output.

SHEAR WALL DESIGN ACI318-99

Technical Note 32
Output Details

This program provides output details that can be printed to a printer or to a text file. The program presents the data in tabular form with column headings. This Technical Note identifies each of the column headings for the pier and spandrel detailed output data and provides a description of what is included in the column. The six types of detailed output available are:

- Simplified pier section design (Table 1).
- Uniform Reinforcing pier section design (Table 2).
- General Reinforcing pier section design (Table 2).
- Uniform Reinforcing pier section check (Table 3).
- General Reinforcing pier section check (Table 3).
- Spandrel design (Table 4).

Each of these types of output is described in the tables provided in Shear Wall Design Technical Note 5 Output Data.