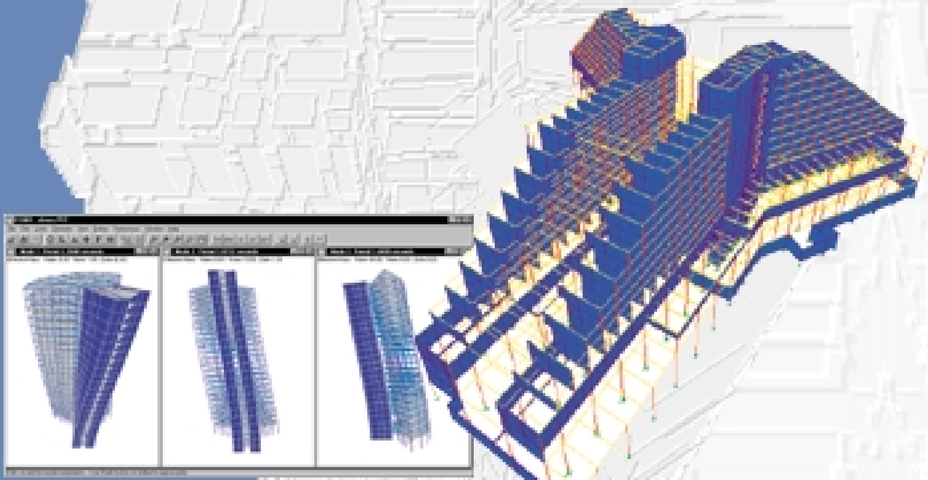

ETABS®

Shear Wall Design Manual

1997 UBC

COMPUTERS & STRUCTURES INC.

STRUCTURAL AND EARTHQUAKE ENGINEERING SOFTWARE

ETABS®

Three Dimensional Analysis and Design of Building Systems

Shear Wall Design Manual for the 1997 UBC

COMPUTERS & STRUCTURES INC.

Computers and Structures, Inc.
Berkeley, California, USA

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DISCLAIMER

Contents

Tip:

If you are just getting started with ETABS Version 7 we suggest that you read Chapters 1 through 10 and then use the rest of the manual as a reference guide on an as-needed basis.

The Table of Contents for this manual consists of a chapter list followed by an expanded table of contents. The chapter list devotes one line to each chapter. It shows you the chapter number (if applicable), chapter title and the pages that the chapter covers. Subheadings are provided in the chapter list section to help give you a sense of how this manual is divided into several different parts.

Following the chapter list is the expanded table of contents. Here all section headers and subsection headers are listed along with their associated page numbers for each chapter in the manual.

When searching through the manual for a particular chapter, the highlighted tabs at the edge of each page may help you locate the chapter more quickly.

If you are new to ETABS we suggest that you read Chapters 1 through 10 and then use the rest of the manual as a reference guide on an as-needed basis.

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Shear Wall Design Manual - Expanded Contents

Notation

1997 UBC Notation

Following is the notation used in this design manual. As much as possible, the notation used in this manual is the same as that in the 1997 UBC.

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 edge member, 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.

N

A_{sc-max} = Maximum area of compression reinforcing steel in a 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-max} = Maximum area of tension reinforcing steel in a 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-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_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.

N

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 6-1.

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 6-1.

DL = Dead load.

E = The earthquake load on a structure. See the section titled "Earthquake Load Component" in Chapter 10.

E_s = Modulus of elasticity of reinforcing steel, psi.

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.

N

Pmax Factor = Factor used to reduce the allowable maximum compressive design strength, unitless. The 1997 UBC specifies this factor to be 0.80. You can revise this factor 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 end of the spandrel.

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

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

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 end 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 end 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.

N

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.

Chapter 1

Introduction

ETABS features powerful and completely integrated modules for the design of steel and concrete frames, composite beams and concrete shear walls. This manual documents design of concrete shear walls using the 1997 UBC in ETABS. The goal of this manual is to provide you with all of the information required to reproduce the ETABS Shear Wall Design postprocessor results using hand calculations.

Overview

Note:

ETABS shear wall design is fully integrated into the ETABS graphical user interface.

ETABS shear wall design is fully integrated into the ETABS graphical user interface. The ETABS graphical interface provides an environment where you can easily design shear walls, study the design results, make appropriate changes (such as revising member properties) and re-examine the design results.

Designs are based on a set of ETABS-defined default design load combinations that can be supplemented by user-defined load combinations.

You have complete control over the program output. You can view or print as much or as little design output as necessary.

The ETABS Shear Wall Design postprocessor designs both wall piers and wall spandrels. The following two subsections discuss each of these items.

Wall Pier Design

The ETABS Shear Wall Design postprocessor can perform two- or three-dimensional designs of wall piers. When ETABS designs a wall pier it considers flexural reinforcement, shear reinforcement and boundary element requirements. There are three different options available in ETABS for the consideration of flexural reinforcement. They are:

1. Perform a simplified design that yields concentrated areas of reinforcing at the ends of the pier. The pier design geometry used in this simplified design is defined in the pier design overwrites. This option is only available if you perform a two-dimensional design of the pier.

2. Use Section Designer to specify the pier design geometry and rebar layout. For this option, the important items in the rebar layout are the bar location and the *relative* size of each bar (relative to other bars). ETABS then reports the percentage of reinforcing steel required to resist the applied loads based on your pier geometry and rebar layout. It also reports the percentage of reinforcing steel actually specified in your rebar layout so that you can gain some perspective on the actual bar sizes that might be required. This option is available for both two- and three-dimensional design of the pier.

3. Use Section Designer to specify the pier design geometry and rebar layout. For this option, the important items in the rebar layout are the bar location and the *actual* size of each bar. ETABS then reports the maximum demand capacity ratio for the pier based on the pier geometry and rebar layout. We strongly recommend that even if you initially use one of the other design options that you always complete your pier design using this option. This pier design option allows you to verify your final design and it is available for both two- and three-dimensional design of the pier.

When the flexural design for the pier is based on a simplified section (item 1 above), the shear design and boundary check are performed at the top and bottom of the pier and are based on the same simplified section.

When the flexural design is based on a Section Designer section (items 2 and 3 above) , the shear design and boundary check are performed at the bottom of the pier only and are based on an effective rectangular section. The process ETABS uses to derive the dimensions for this effective rectangular section is described in Chapter 6. You can revise the dimensions of this effective section in the pier design overwrites. For three-dimensional piers two effective sections are defined. One is for shear in the pier local 2-axis direction and the other is for shear in the pier local 3-axis direction.

Note that when the ETABS Shear Wall Design postprocessor checks specified flexural reinforcing (item 3 above), it designs the shear reinforcing. There is no mechanism available in ETABS to specify the pier shear reinforcing and have it verified by the program.

Wall Spandrel Design

In ETABS wall spandrels must be two-dimensional. When ETABS designs a wall spandrel it reports required areas of concentrated flexural reinforcement at the top and bottom of the spandrel, and the required shear reinforcement.

The spandrel design geometry is defined in the spandrel design overwrites. The design geometry may be either a rectangular beam or a T-beam.

ETABS only designs spandrels; it does not check them. There is no mechanism available in ETABS to specify the spandrel reinforcing (flexural or shear reinforcing) and have it verified by the program.

Organization of Manual

This manual is organized as follows:

Tip:

We recommend that you read Chapters 1 through 10 of this manual and then use the rest of the manual as a reference guide on an as-needed basis.

- **Chapter 1 (this chapter):** General introduction.
- **Chapters 2 through 4:** Information on how to use ETABS to design shear walls.
- **Chapters 5 through 10:** Documentation of background information for 1997 UBC concrete shear wall design using ETABS.
- **Chapters 11 through 15:** Documentation of the 1997 UBC concrete shear wall design algorithm used by ETABS.
- **Chapters 16 through 19:** Documentation of the 1997 UBC concrete shear wall output.

Other Reference Information

ETABS Help

You can access the ETABS Help by clicking the **Help menu > Search for Help On** command. You can also access context-sensitive help by pressing the F1 function key on your keyboard when a dialog box is displayed.

Readme.txt File

Be sure to read the readme.txt file that is on your CD. This provides the latest information about the program. Some of the information in the readme.txt file may provide updates to what is published in this manual. If you download an updated version of the program be sure to download and read the updated readme.txt file.

Recommended Initial Reading

We recommend that you initially read Chapters 1 through 10 of this manual. You can then use the remainder of this manual as a reference on an as-needed basis.

Chapter 2

Shear Wall Design Process

Note:

Shear wall design in ETABS is an iterative process.

This chapter describes three typical shear wall design processes that might occur for a new building. Note that the sequence of steps you may take in any particular design may vary from this but the basic process will be essentially the same.

The design process used varies slightly depending on the type of wall pier design that you want to do. The three types of pier design considered in this chapter are:

- Two-dimensional pier design resulting in concentrated reinforcing at the ends of the piers.
- Two-dimensional pier design resulting in relatively uniformly distributed reinforcing in the piers.
- Three dimensional pier design.

Typical Design Process for 2D Piers with Concentrated Reinforcing

Note:

See Chapter 8 for discussion of the shear wall preferences.

1. Use the **Options menu > Preferences > Shear Wall Design** command to review the shear wall design preferences and revise them if necessary. Note that there are default values provided for all shear wall design preferences so it is not actually necessary for you to define any preferences unless you want to change some of the default preference values.

2. Create the building model.

3. Assign the wall pier and wall spandrel labels. Use 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 to do this. Refer to the ETABS User's Manual for additional information on pier and spandrel labeling.

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

Note:

See Chapter 9 for discussion of the shear wall overwrites.

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 you must select piers or spandrels first before using these commands. Also note that there are default values provided for all pier and spandrel design overwrites so it is not actually necessary for you to define any overwrites unless you want to change some of the default overwrite values.

   Note that the overwrites can be assigned before or after the analysis is run.

   <u>Important note about selecting piers and spandrels:</u> You can select a pier or spandrel simply by selecting any line or area object that is part of the pier or spandrel.

6. If you want to use any design load combinations other than the default ones created by ETABS for your shear wall design then click the **Design menu > Shear Wall Design > Select Design Combo** command. Note that you must have already created your own design combos by clicking the **Define menu > Load Combinations** command.

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. To do this you might do 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.

   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 you are not currently displaying design results you can 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 a few piers or spandrels before using this command then data is printed only for the selected elements.

Note:

See Chapter 4 for discussion of interactive shear wall design. This is a very powerful tool.

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

10. Create wall pier check sections with user-defined (actual) reinforcing specified for the wall piers using the Section Designer utility. Use the **Design menu > Shear Wall Design > Define Pier Sections for Checking** command to define the sections in Section Designer. Be sure to indicate that the re-

inforcing is to be *checked* in the Pier Section Data dialog box. Use the **Design menu > Shear Wall Design > Assign Pier Sections for Checking** command to assign these sections to the piers. Rerun the design and verify that the actual flexural reinforcing provided is adequate.

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

12. Print or display selected shear wall design results if desired.

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.

Typical Design Process for 2D Piers with Uniform Reinforcing

13. Use the **Options menu > Preferences > Shear Wall Design** command to review the shear wall design preferences and revise them if necessary. Note that there are default values provided for all shear wall design preferences so it is not actually necessary for you to define any preferences unless you want to change some of the default preference values.

Note:

See Chapter 8 for discussion of the shear wall preferences.

14. Create the building model.

15. Assign the wall pier and wall spandrel labels. Use 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 to do this. Refer to the ETABS User's Manual for additional information on pier and spandrel labeling.

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

Note:

See Chapter 9 for discussion of the shear wall overwrites.

17. 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 you must select piers or spandrels first before using these commands. Also note that there are default values provided for all pier and spandrel design overwrites so it is not actually necessary for you to define any overwrites unless you want to change some of the default overwrite values.

    Note that the overwrites can be assigned before or after the analysis is run.

    Important note about selecting piers and spandrels: You can select a pier or spandrel simply by selecting any line or area object that is part of the pier or spandrel.

18. If you want to use any design load combinations other than the default ones created by ETABS for your shear wall design then click the **Design menu > Shear Wall Design > Select Design Combo** command. Note that you must have already created your own design combos by clicking the **Define menu > Load Combinations** command.

19. Create wall pier design sections with actual rebar placement specified for the wall piers using the Section Designer utility. Use the **Design menu > Shear Wall Design > Define Pier Sections for Checking** command to define the sections in Section Designer. Be sure to indicate that the reinforcing is to be *designed* in the Pier Section Data dialog box. Use the **Design menu > Shear Wall Design > Assign Pier Sections for Checking** command to assign these sections to the piers.

    Note that at this point the actual bar size specified in the Section Designer pier sections is not important. What is important is the relative bar size, that is, the size of one rebar in the pier section to the other bars in the section. The program always maintains this relationship.

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

21. Review the shear wall design results. To do this you might do 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.

    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 you are not currently displaying design results you can 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 a few piers or spandrels before using this command then data is printed only for the selected elements.

Note:

See Chapter 4 for discussion of interactive shear wall design. This is a very powerful tool.

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

23. 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 Pier Sections for Checking** 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 dialog box. Rerun the design and verify that the actual flexural reinforcing provided is adequate.

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

25. Print or display selected shear wall design results if desired.

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.

Typical Design Process for 3D Piers

1. Use the **Options menu > Preferences > Shear Wall Design** command to review the shear wall design preferences and revise them if necessary. Note that there are default values provided for all shear wall design preferences so it is not actually necessary for you to define any preferences unless you want to change some of the default preference values.

Note:

See Chapter 8 for discussion of the shear wall preferences.

2. Create the building model.

3. Initially it is useful to perform a 2D design so that a shear check is performed. Assign wall pier and wall spandrel labels for the 2D design. Use 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 to do this. Refer to the ETABS User's Manual 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 you must select piers or spandrels first before using these commands. Also note that there are default values provided for all pier and spandrel design overwrites so it is not actually necessary for you to define any overwrites unless you want to change some of the default overwrite values.

   Note that the overwrites can be assigned before or after the analysis is run.

Note:

See Chapter 9 for discussion of the shear wall overwrites.

Important note about selecting piers and spandrels: You can select a pier or spandrel simply by selecting any line or area object that is part of the pier or spandrel.

6. If you want to use any design load combinations other than the default ones created by ETABS for your shear wall design then click the **Design menu > Shear Wall Design > Select Design Combo** command. Note that you must have already created your own design combos by clicking the **Define menu > Load Combinations** command.

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. To do this you might do 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.

   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 you are not currently displaying design results you can 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 a few piers or spandrels before using this command then data is printed only for the selected elements.

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

Note:

See Chapter 4 for discussion of interactive shear wall design. This is a very powerful tool.

10. When you are satisfied with the shear design, relabel the wall piers so that you can perform a 3D design. Use the **Assign menu > Frame/Line > Pier Label** and the **Assign menu > Shell/Area > Pier Label** commands to do this. Refer to the ETABS User's Manual for additional information on pier and spandrel labeling.

11. Create wall pier design sections with actual rebar placement specified for the wall piers using the Section Designer utility. Use the **Design menu > Shear Wall Design > Define Pier Sections for Checking** command to define the sections in Section Designer. Be sure to indicate that the reinforcing is to be *designed* in the Pier Section Data dialog box. Use the **Design menu > Shear Wall Design > Assign Pier Sections for Checking** command to assign these sections to the piers.

    Note that at this point the actual bar size specified in the Section Designer pier sections is not important. What is important is the relative bar size, that is, the size of one rebar in the pier section to the other bars in the section. The program always maintains this relationship.

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

13. Review the shear wall design results.

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

15. 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 Pier Sections for Checking** 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 dialog box. Rerun the design and verify that the actual flexural reinforcing provided is adequate.

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

17. Print or display selected shear wall design results if desired.

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.

Chapter 3

Design Menu Commands for Shear Wall Design

This chapter describes each of the shear wall design menu commands that are available in ETABS. You can find these commands by clicking **Design menu > Shear Wall Design**.

Select Design Combo

Click the **Design menu > Shear Wall Design > Select Design Combo** command to open the Design Load Combinations Selection dialog box. Here you can review the default shear wall design load combinations defined by ETABS and/or you can designate your own design load combinations.

In the dialog box all of the available design load combinations are listed in the List of Combos list box. The design load combinations actually used in the design are listed in the Design Combos list box. You can use the **Add** button and the **Remove** button to move load combinations into and out of the Design Combos list box. Use the **Show** button to see the definition of a design load combination. All three buttons act on the highlighted design load combination. You can use the Ctrl and Shift keys to make multiple selections in this dialog box for use with the **Add** and **Remove** buttons, if desired.

The default shear wall design load combinations have names like DWAL1, etc.

View/Revise Pier Overwrites

Note:

See Chapter 9 for discussion of the shear wall overwrites.

Use the **Design menu > Shear Wall Design > View/Revise Pier Overwrites** command to review and/or change the wall pier overwrites. You may not need to assign any wall pier overwrites; however the option is always available to you.

The wall pier design overwrites are basic properties that apply only to the piers that they are specifically assigned to. Note that inputting 0 for most pier overwrite items means to use the ETABS default value for that item.

You can select one or more piers for which you want to specify overwrites. In the overwrites form there is a checkbox to the left of each item. You must check this box for any item you want to change in the overwrites. If the check box for an overwrite item is not checked when you click the **OK** button to exit the overwrites form, then no changes are made to the pier overwrite item. This is true whether you have one pier selected or multiple piers selected.

View/Revise Spandrel Overwrites

Use the **Design menu > Shear Wall Design > View/Revise Spandrel Overwrites** command to review and/or change the wall spandrel overwrites. You may not need to assign any wall spandrel overwrites; however the option is always available to you.

The wall spandrel design overwrites are basic properties that apply only to the spandrels that they are specifically assigned to. Note that inputting 0 for most spandrel overwrite items means to use the ETABS default value for that item.

You can select one or more spandrels for which you want to specify overwrites. In the overwrites form there is a checkbox to the left of each item. You must check this box for any item you want to change in the overwrites. If the check box for an item is not checked when you click the **OK** button to exit the overwrites form then no changes are made to the item. This is true whether you have one spandrel selected or multiple spandrels selected.

Define Pier Sections for Checking

To define a pier section with reinforcing for checking click the **Design menu > Shear Wall Design > Define Pier Sections for Checking** command. This command allows you to define a pier section using the Section Designer utility. See the Section Designer Manual for more information.

Assign Pier Sections for Checking

Use the **Design menu > Shear Wall Design > Assign Pier Sections for Checking** command to assign a pier a section that has been defined using the Section Designer utility.

Start Design/Check of Structure

To run a shear wall design simply click **Design menu > Shear Wall Design > Start Design/Check of Structure**. This option will not be available if you have not first run a building analysis. It will also be unavailable if there are no piers or spandrels defined (i.e., assigned a pier or spandrel label) in the model.

If you have selected piers and/or spandrels when you click this command then only the selected piers and/or spandrels are designed. If no piers and/or spandrels are selected when you click this command then all piers and spandrels are designed.

Interactive Wall Design

Note:

See Chapter 4 for discussion of interactive shear wall design.

Right click on a pier or spandrel while the design results are displayed on it to enter the interactive design mode and interactively design the pier or spandrel in the Wall Design dialog box. If you are not currently displaying design results you can 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 pier or spandrel.

Display Design Info

You can review some of the results of the shear wall design directly on the ETABS model using the **Design menu > Shear Wall Design > Display Design Info** command. The types of things you can display are reinforcing requirements, capacity ratios and boundary element requirements.

Reset All Pier/Spandrel Overwrites

Note:

See Chapter 9 for discussion of the shear wall overwrites.

The **Design menu > Shear Wall Design > Reset All Pier/Spandrel Overwrites** command resets the pier and spandrel overwrites for all pier and spandrel elements back to their default values. It is not necessary to make a selection before using the **Reset All Pier/Spandrel Overwrites** command. This command automatically applies to all pier and spandrel elements.

Delete Wall Design Results

The **Design menu > Shear Wall Design > Delete Wall Design Results** command deletes all of the shear wall results. It is not necessary to make a selection before using the **Delete Wall Design Results** command. This command automatically applies to all pier and spandrel elements.

Deleting your shear wall results will reduce the size of your ETABS database (*.edb) file.

At times ETABS automatically deletes your shear wall design results. Following are some of the reasons that this might happen:

- Anytime you unlock your model ETABS deletes your shear wall design results.

- Anytime you use the **Design menu > Shear Wall Design > Select Design Combo** command to change a design load combination ETABS deletes your shear wall design results.

- Anytime you use the **Define menu > Load Combinations** command to change a design load combination ETABS deletes your shear wall design results.

- Anytime you use the **Options menu > Preferences > Shear Wall Design** command to change any of the shear wall design preferences ETABS deletes your shear wall design results.

- Anytime you do something that causes your static nonlinear analysis results to be deleted then the design results for any load combination that includes static nonlinear forces are also deleted. Typically your static nonlinear analysis and design results are deleted when you do one of the following:

  ✓ Use the **Define menu > Frame Nonlinear Hinge Properties** command to redefine existing or define new hinges.

  ✓ Use the **Define menu > Static Nonlinear/Pushover Cases** command to redefine existing or define new static nonlinear load cases.

  ✓ Use the **Assign menu > Frame/Line > Frame Nonlinear Hinges** to add or delete hinges.

  Again note that this only deletes results for load combinations that include static nonlinear forces.

Chapter 4

Interactive Shear Wall Design and Review

General

Interactive shear wall design and review is a powerful mode that allows you to quickly view design results on the screen for a specific pier or spandrel. In this mode you can easily modify design parameters (overwrites) and immediately see the new results.

Note:

Interactive shear wall design and review is a powerful tool for reviewing pier and spandrel design results on the screen.

Right click on a wall pier or spandrel while the design results are displayed to enter the interactive design and review mode. If you are not currently displaying design results you can 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 object that you right click, then a box pops up where you can choose to enter the interactive design and review mode for either the pier or the spandrel.

The following sections describe the interactive pier design and review and the interactive spandrel design and review.

Interactive Pier Design and Review

Note:

Most of this chapter discusses the output that is displayed during interactive shear wall design and review. You may have to read other sections of this manual first (e.g., portions of Chapters 5 through 15) to fully understand the output described in this chapter.

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

- Design of a pier specified as a Simplified Section.
- Design of a pier specified using a Section Designer section.
- Check of a pier specified using a Section Designer section.

The output associated with each of these three choices is described in detail in the subsections below.

There are also several command buttons available on these forms. They include the **Combos**, **Overwrites**, **Section Top** and **Section Bot** buttons. (Note that the **Section Top** and **Section Bot** buttons do not appear on the Simplified Section form. The function of each of these buttons is described in subsections below.

Design of a Simplified Section

When you right click on a simplified pier section for interactive design the Pier Design dialog box appears. There is some general information identifying and locating the pier at the top of this form. There is output information for flexural design, shear design and the boundary element check. There are also several command buttons on the form. All of these items are described in the subsections below.

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. You should 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 designating the location of the reported reinforcing steel.

- **Edge Length:** Length of the ETABS-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 you have specified specific rebar area units in the shear wall preferences, then those units are displayed in the column heading. If no specific units are displayed in the column heading, then 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.

Compression Design

- **Station Location:** This is Left Top, Right Top, Left Bottom or Right Bottom designating the location of the reported reinforcing steel.
- **Edge Length:** Length of the ETABS-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 you have specified specific rebar area units in the shear wall preferences, then those units are displayed in the column heading. If no specific units are displayed in the column heading, then 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 the subsection titled "EQ Factor" in Chapter 9 for more information.
- **Station Location:** This is either Top 2-dir or Bot 2-dir designating the location (top or bottom) of the reported

shear reinforcing steel and the direction of force (pier local 2-axis) for which the steel is provided.

- **Rebar:** Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 either Top 2-dir or Bot 2-dir designating 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.

Note:

See Chapter 11 for more information on the boundary element check.

- **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 done by ETABS because he ratio P_u/P_o is greater than or equal to 0.35.

  When this item is Not Needed or Not Checked ETABS 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 Pu/Po value. Otherwise ETABS 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 then ETABS does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Design of a Section Designer Section

When you right click for interactive design of a pier section that is assigned a Section Designer section and has been designed by ETABS, the Pier Design dialog box appears. There is some general information identifying and locating the pier at the top of this form. There is output information for flexural design, shear design and the boundary element check. There are also several command buttons on the form. All of these items are described in the subsections below.

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

Tip:

Do not confuse the Required Reinforcing Ratio and the Current Reinforcing Ratio. The important item is the Required Reinforcing Ratio.

- **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 designating 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 ETABS, 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.

  For example, suppose the Current Reinf Ratio (see next item) is 0.0200 and the Required Reinf Ratio is 0.0592. Then 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 Section Designer section, with actual reinforcing, that is checked by ETABS (not designed).

Note:

The area of the Section Designer 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.

- **Current Reinf 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.

- **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.

Shear Design Data

- **EQF:** A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See the subsection titled "EQ Factor" in Chapter 9 for more information.

- **Station Location:** This is Top 2-dir, Top 3-dir, Bot 2-dir or Bot 3-dir designating the location (top or bottom) of the reported shear reinforcing steel and the direction of force (pier local 2-axis or pier local 3-axis) for which the steel is provided. The Top 3-dir and Bot 3-dir items only appear if the Design Pier is 3D item in the pier overwrites is set to Yes for the pier considered.

Note:

The flexural design of a Section Designer pier section is always a PMM design that considers both M2 and M3 bending. This is true whether the pier is designated in the overwrites as 2D or 3D.

- **Rebar:** Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 2-dir, Top 3-dir, Bot 2-dir or Bot 3-dir designating the location (top or bottom) of the boundary element check and the direction of force (pier local 2-axis or pier local 3-axis) for which the boundary elements are checked. The Top 3-dir and Bot 3-dir items only appear if the Design Pier is 3D item in the pier overwrites is set to Yes for the pier considered.

Note:

See Chapter 11 for more information on the boundary element check.

- **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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35.

  When this item is Not Needed or Not Checked ETABS 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 Pu/Po value. Otherwise ETABS 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 then ETABS does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Check of a Section Designer Section

When you right click for interactive design of a pier section that is assigned a Section Designer section and is designated to be checked (not designed) by ETABS, the Pier Design dialog box appears. There is some general information identifying and locating the pier at the top of this form. There is output information for the flexural check, shear design and the boundary element check. There are also several command buttons on the form. All of these items are described in the subsections below.

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 Section Designer pier section is always a PMM design that considers both M2 and M3 bending. This is true whether the pier is designated in the overwrites as 2D or 3D.

Shear Design Data

- **EQF:** A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See the subsection titled "EQ Factor" in Chapter 9 for more information.

- **Station Location:** This is Top 2-dir, Top 3-dir, Bot 2-dir or Bot 3-dir designating the location (top or bottom) of the reported shear reinforcing steel and the direction of force (pier local 2-axis or pier local 3-axis) for which the steel is provided. The Top 3-dir and Bot 3-dir items only appear if the Design Pier is 3D item in the pier overwrites is set to Yes for the pier considered.

- **Rebar:** Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 2-dir, Top 3-dir, Bot 2-dir or Bot 3-dir designating the location (top or bottom) of the boundary element check and the direction of force (pier local 2-axis or pier local 3-axis) for which the boundary elements are checked. The Top 3-dir and Bot 3-dir items only appear if the Design Pier is 3D item in the pier overwrites is set to Yes for the pier considered.

Note:

See Chapter 11 for more information on the boundary element check.

- **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 done by ETABS because he ratio P_u/P_o is greater than or equal to 0.35.

  When this item is Not Needed or Not Checked ETABS 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 Pu/Po value. Otherwise ETABS 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 then ETABS does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Combos Button

You can click the **Combos** button to access and make *temporary* revisions to the design load combinations considered for the pier. 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 Wall

Design dialog box regardless of whether you click **OK** or **Cancel** to exit it.

Overwrites Button

You can click the **Overwrites** button to access and make revisions to the pier overwrites and then immediately see the new design results. If you modify some overwrites in this mode and you exit both the Pier Design Overwrites dialog box and the Pier Design dialog box by clicking their respective **OK** buttons then the changes you made to the overwrites are permanently saved.

When you exit the Pier Design Overwrites form by clicking the **OK** button the changes are temporarily saved. If you then exit the Pier Design dialog box by clicking the **Cancel** button, the changes you made to the pier overwrites are considered temporary only and are not permanently saved. Permanent saving of the overwrites does not actually occur until you click the **OK** button in the Pier Design dialog box.

Section Top and Section Bot Buttons

These buttons are only visible if you are designing or checking a pier with a Section Designer section assigned to it. Clicking these buttons opens Section Designer in a locked (read-only) mode where you can view the Section Designer section assigned to the pier. Clicking the **Section Top** button allows you to view the section assigned to the top of the pier. Similarly, clicking the **Section Bot** button allows you to view the section assigned to the bottom of the pier.

While in Section Designer you can review the geometry of the section and the size and location of the rebar. However you can not 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 are through reviewing the section in Section Designer click the Section Designer **File menu > Return to ETABS** command to return to the Pier Design dialog box.

Interactive Spandrel Design and Review

When you right click on a spandrel for interactive design the Spandrel Design dialog box appears. There is some general information identifying and locating the spandrel at the top of this form. There is output information for both flexural and shear design and there are several command buttons on the form. All of these items are described in the subsections below.

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 designating that the output reported is for the left or right end of the spandrel.
- **Top Steel Area:** The area of top steel required for the Top Steel Combo. If you have specified specific rebar

area units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 4-1.

$$\text{Top Steel Ratio} = \frac{A_{s\ top}}{t_s\left(h_s - d_{r-top}\right)} \qquad \text{Eqn. 4-1}$$

- **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 designating 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 you have specified specific rebar area units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 4-2.

$$\text{Bot Steel Ratio} = \frac{A_{s\ top}}{t_s\left(h_s - d_{r-bot}\right)} \qquad \text{Eqn. 4-2}$$

- **Bot Steel Combo:** The name of the design load combination that requires the most bottom steel in the spandrel.

- **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 the subsection titled "EQ Factor" in Chapter 9 for more information.

Design Data for all Spandrels

- **Station Location:** This is either Left or Right designating 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 you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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.

Additional Design Data for Seismic Spandrels Only

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.

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 designating 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 you have specified specific rebar area units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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.

Combos Button

You can click the **Combos** button to access and make *temporary* revisions to the design load combinations considered for the 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 Spandrel Design dialog box regardless of whether you click **OK** or **Cancel** to exit it.

Overwrites Button

You can click the **Overwrites** button to access and make revisions to the spandrel overwrites and then immediately see the new design results. If you modify some overwrites in this mode and you exit both the Spandrel Design Overwrites dialog box and the Spandrel Design dialog box by clicking their respective **OK** buttons then the changes you made to the overwrites are permanently saved.

When you exit the Spandrel Design Overwrites form by clicking the **OK** button the changes are temporarily saved. If you then exit the Spandrel Design dialog box by clicking the **Cancel** button the changes you made to the spandrel overwrites are considered temporary only and are not permanently saved. Permanent saving of the overwrites does not actually occur until you click the **OK** button in the Spandrel Design dialog box.

Chapter 5

General Design Information

This chapter presents some basic information and concepts that you should know prior to designing or checking shear walls using ETABS.

Defining Piers and Spandrels

Note:

The ETABS User's Manual provides information on defining wall piers and spandrels.

In ETABS you must first define a wall pier or spandrel before you can get output forces for it and before you can design it. You define piers and spandrels by assigning them labels. The ETABS User's Manual provides information on defining (labeling) wall piers and spandrels. For information on defining wall piers, review the items listed in the ETABS User's Manual under "piers, labels." For information on defining wall spandrels, review the items listed in the ETABS User's Manual under "spandrels, labels."

Piers are defined by assigning pier labels to vertical area objects (walls) and/or 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.

Tip:

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

Important note: Do not confuse pier labels with the Section Designer pier section names that can be assigned to the piers. The pier labels are used to define/identify the pier. All piers have a pier label. Pier sections are section properties that are defined using the Section Designer utility. A pier may have a pier section assigned to it, but it is not necessary.

Spandrels are defined by assigning spandrel labels to vertical area objects (walls) and/or 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.

Analysis Sections versus 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 ETABS model that make up the pier or spandrel section. The analysis section for wall piers is simply the assemblage of wall and column sections that make up the pier. Similarly, the analysis section for spandrels is simply the assemblage of wall and beam sections that make up the spandrel. The analysis is based on these section properties and the thus the design forces are based on these analysis section properties.

The design section is completely separate from the analysis section. Two types of pier design sections are available. They are:

- **Simplified 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. The pier local axes are described in the ETABS User's Manual.

  In addition, you can, if desired, specify thickened edge members at one or both ends of the simplified pier section. You can not 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.

- **Section Designer Section:** This pier section is defined in the Section Designer utility. You define the pier geometry and the reinforcing in Section Designer. A Section Designer section can be used for design or for checking wall piers. Section Designer sections can be planar or they can be three-dimensional.

Note:

Wall pier design sections are discussed in Chapter 6.

See Chapter 6 for detailed discussion 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. The spandrel local axes are described in the ETABS User's Manual. Spandrel sections are always planar.

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

Note:

Wall spandrel geometry is discussed in Chapter 7.

See Chapter 7 for a detailed discussion of spandrel design sections.

The pier and spandrel design sections are designed for the forces obtained from the ETABS 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.

Units

Note:

You can use any set of units in ETABS and you can change the units on the fly.

For shear wall design in ETABS any set of consistent units can be used for input. You can change the system of units you are using at any time. Typically design codes are based on one specific set of units. The 1997 UBC requirements are based on pound-inch-seconds units. For simplicity and consistency the documentation in this manual is typically presented in pound-inch-seconds units.

In the shear wall design preferences you can specify special units for concentrated and distributed areas of reinforcing. These units are then used for the reinforcing in the model regardless of the current model units that are displayed in the drop-down box on the status bar (or within a specific dialog box). 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.

Note:

ETABS uses special units for reinforcing. These units are specified in the shear wall preferences.

The current units option uses whatever units are currently displayed in the drop-down box on the status bar (or within a specific dialog box). If the current length units are feet, then 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.

Design Station Locations

ETABS designs wall piers at stations located at the top and bottom of the pier only. If you want to design at the mid-height of a pier then you need to break the pier up into two separate "half-height" piers.

ETABS designs wall spandrels at stations located at the left and right ends of the spandrel only. If you want to design at the mid-length of a spandrel then you need to break the spandrel up into two separate "half-length" piers. Note that if you break a spandrel up 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 up into pieces you should calculate the seismic diagonal shear reinforcing separately by hand.*

Design Load Combinations

Note:

See Chapter 10 for more information on design load combinations.

ETABS creates a number of default design load combinations for shear wall design. You can add in your own design load combinations if you wish. You can also modify or delete the ETABS default load combinations if desired. There is no limit to the number of design load combinations you can specify.

To define a design load combination you simply specify one or more load cases each with its own scale factor. See Chapter 10 for more information on design load combinations.

Wall Meshing and Gravity Loading

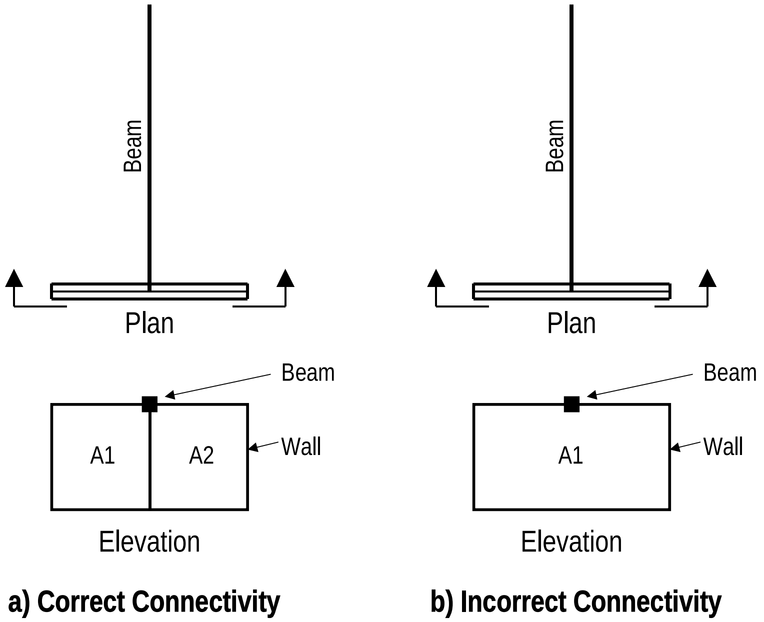
You must manually mesh the walls in your model. There is no automatic wall meshing in ETABS. Discussion of the meshing options available is provided in the ETABS User's Manual. This section provides a few additional comments about wall meshing.

When you frame a beam into a wall, the wall must be meshed such that the beam connects to a corner point of one or more of the area objects that make up the wall. The connectivity between the beam and the wall is achieved when the end of the beam connects to a corner point of an area object that makes up the wall.

Consider the example shown in Figure 5-1 which shows a beam framing into the center of the top edge of a wall. Figure 5-1a shows the correct connectivity. In this case the wall has been meshed into two area objects labeled A1 and A2. The beam, top right corner or area A1 and top left corner of area A2 all are connected together. For this case the beam is supported by the wall and loads can be transferred from the beam to the wall.

Figure 5-1b shows an example of incorrect connectivity. In this case the wall is made up of a single area object labeled A1. There is no connection between the beam and the wall because the beam does not frame into a corner point of area object A1. For this case the beam is *not* supported by the wall and loads can *not* be transferred from the beam to the wall. This type of modeling could lead to instability errors when you try to analyze the model because the beam is not properly supported.

Figure 5-1: Example of beam connecting to a wall



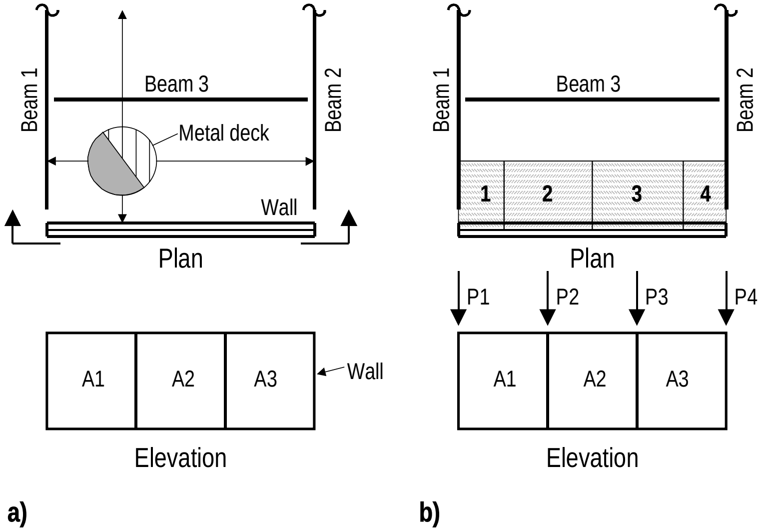
It is important to understand that loads are only transferred to walls at the corner points of the area objects that make up the wall. Consider the example shown in Figure 5-2a which illustrates the load transfer associated with a floor deck connecting to a wall. The transfer of load only occurs at the joints (corner points of the area objects.

Figure 5-2b 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.
- Load P4 comes from the end reaction of Beam 2 and from the uniform load in the floor area labeled 1.

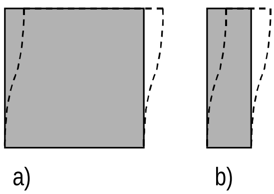
Thus the uniform floor load is not transferred to the wall as a uniform load. Instead it transfers as a series of point loads. The

Figure 5-2:
Example of floor deck connecting to a wall



point loads are located at the corner points of the area objects that make up the wall.

Consider Figure 5-3 which shows three types of deformation that a single shell element could experience. A single shell element in ETABS 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.



For example consider the shell elements shown in the sketch to the left. 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 5-4. Figure 5-4a 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 5-3:
Shell element deformation

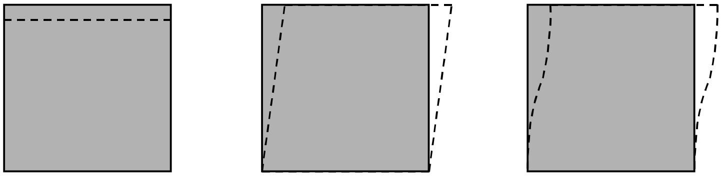


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Figure 5-4b shows the same wall with the opening shifted to the left such that the left pier becomes skinny. In this case bending deformations may be significant in that pier and thus it is meshed into two shell elements.

Figure 5-4c 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.

There is no specific rule for when you should 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 one shell element is worse than 3 to 1 then you should consider additional meshing of the element to adequately capture the bending deformation.

Using Frame Elements to Model Spandrels

When you use 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 size shell elements provide different fixities and thus different analysis results.

In general, for models where the spandrels are modeled using frame elements, you get better analysis results when you have a coarser shell element mesh, that is when the shell elements that the beam connects to are larger. If the shell element mesh is re-

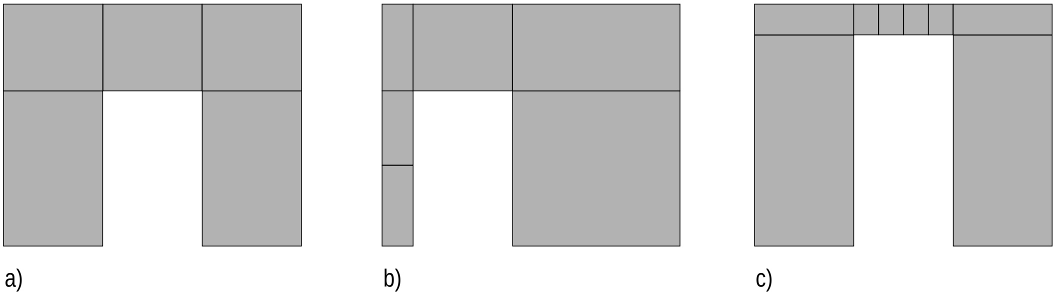


Figure 5-4:
Shell element meshing example for piers and spandrels

fined then you may want to extend 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 then you should either extend the beam into the wall as mentioned above or you should consider modeling the spandrel with shell elements instead of a frame element.

Chapter 6

Wall Pier Design Sections

General

You can define a simplified two-dimensional wall pier design section in the pier design overwrites. Alternatively, you can define a two- or three-dimensional wall pier design section using the Section Designer utility and then assign it to the pier element.

When designing a simplified pier design section, ETABS reports concentrated areas of flexural reinforcing at the ends of the pier, the required shear reinforcing and special boundary element requirements. The design is performed for sections at the top and the bottom of the pier. The dimensions and properties associated with the simplified pier design section are described later in this chapter in the section titled "Simplified Pier Design Dimensions and Properties."

When *designing* (not checking) a Section Designer pier design section ETABS reports the required percentage of flexural reinforcing, the required shear reinforcing and special boundary element requirements. The reported percentage of flexural reinforcing is assumed to be distributed in the same proportion as the reinforcing that was specified in the design section.

When the pier design section is a Section Designer section, the shear design and boundary element check are only done for the forces and the section that occur at the bottom of the pier. This design is based on an effective rectangular section that ETABS derives from the specified Section Designer section. When a three-dimensional design is performed, separate effective rectangular sections are derived for shear in the pier local 2-axis direction and the pier local 3-axis direction. The material property used for the effective sections is the base material property specified for the Section Designer section. The section titled "Section Designer Pier Effective Section for Shear", occurring later in this chapter describes how ETABS calculates the default dimensions for the effective rectangular sections. Note that you can modify the default design dimensions used for the shear design and boundary member check in the pier design overwrites.

When *checking* (not designing) a Section Designer pier design section ETABS reports the demand capacity ratio for flexure. In addition it *designs* and reports the required shear reinforcing and special boundary element requirements. The shear and boundary element design is based on an effective rectangular section as described in the previous paragraph.

Simplified Pier Design Dimensions and Properties

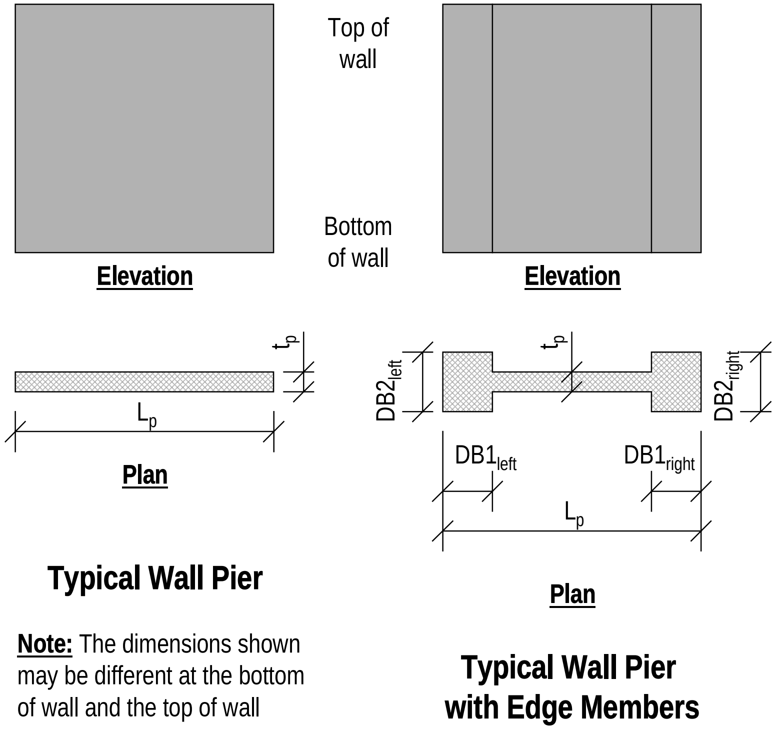
This section describes the design dimensions and the material properties associated with the simplified pier design section.

Design Dimensions

Figure 6-1 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.

Figure 6-1:
Typical wall pier dimensions used for simplified design



Note:

The wall pier simplified design dimensions are specified in the pier design overwrites. The design dimensions can, if desired, be different at the top and bottom of the pier.

- 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.

How ETABS Calculates the Default Dimensions

This section describes how ETABS 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:

ETABS automatically picks up the default design dimensions of a pier element from the assignments made to the objects associated with the pier. You can revise the ETABS default geometry in the pier design overwrites.

ETABS 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 this case ETABS picks up the length from the line objects (columns).

ETABS 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.

There are two ways you can check the thickness:

- Click the **Design menu > Shear Wall Design > Display Design Info** command, click the Design Input radio button 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 Pier Overwrites** command.

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

Material Properties

The design material property used for the design of a wall pier is picked up from the first defined area object that is associated with the pier. If there are no area objects associated with the pier then the material property is taken from the first defined line object associated with the pier. There is no way for you as a user to know or tell which object area was defined first. Thus, if you have the condition where a pier is made up of different objects that have different material properties assigned to them, then you should check the pier material property carefully (using one of the two methods described in the previous section for checking the pier thickness) to make sure the material property is what you want. If it isn't, you can revise the material property in the pier design overwrites.

Section Designer Pier Effective Section for Shear

You can define a design section for any wall pier using Section Designer. The process for this is described in the Section Designer Manual. The pier geometry and rebar layout specified in Section Designer are used for the flexural design/check of the pier. In addition, when a Section Designer section is assigned to a pier, ETABS derives an effective rectangular pier based on the geometry of the Section Designer section. This effective rectangular pier is used for the shear design and boundary elements checks done for the pier.

When three-dimensional design is performed, two effective piers are created. One effective pier is for shear forces acting in the pier local 2-axis direction and the other is for shear forces acting in the pier local 3-axis direction.

Important note: When the shear design and boundary element check is done for a pier that is assigned Section Designer pier sections, the shear design and boundary element check is *only performed at the bottom of the pier*. Thus the forces used for these checks are those at the bottom of the pier and the default dimensions of the effective rectangular pier are based on the pier section assigned to the bottom of the pier.

The effective rectangular section is defined by a length, a thickness, and a material property. The material property used is the base material property specified for the Section Designer pier section.

For shear forces acting in the pier local 2-axis direction the default length is measured parallel to the local 2-axis. The default length is taken as the distance measured parallel to the pier local 2-axis from the point on the section with the *smallest* local 2-axis coordinate to the point with the *largest* local 2-axis coordinate.

For shear forces acting in the pier local 3-axis direction the default length is measured parallel to the local 3-axis. The default length is taken as the distance measured parallel to the pier local 3-axis from the point on the section with the *smallest* local 3-axis coordinate to the point with the *largest* local 3-axis coordinate.

For shear forces acting in either the pier local 2-axis direction or the pier local 3-axis direction the default thickness is calculated by dividing the total area of the bottom of the pier by the length in the 2-axis or 3-axis direction respectively.

Chapter 7

Wall Spandrel Design Sections

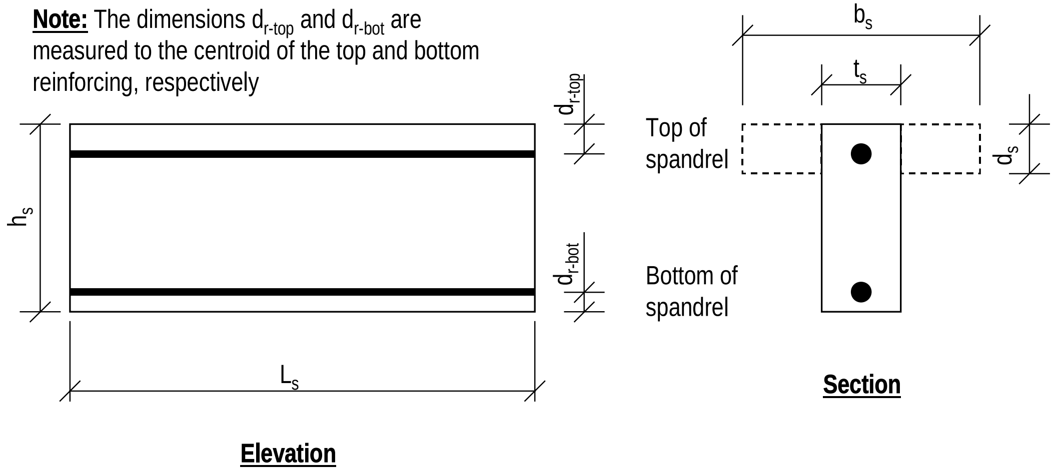
In ETABS all wall spandrels are two-dimensional. ETABS determines the wall spandrel design dimensions and material properties automatically. You can modify the dimensions and properties in the spandrel design overwrites.

Note that you can specify different dimensions at the left and right ends of a spandrel.

Wall Spandrel Design Dimensions

Figure 7-1 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 L_s. This is the horizontal length of the wall spandrel in plan.



(Above) ***Figure 7-1:*** *Typical wall spandrel dimensions*

- 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.
- 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.

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.

Default Design Dimensions

This section describes how ETABS 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.

ETABS 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 this case ETABS picks up the depth from the line objects (beams).

ETABS 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:

ETABS automatically picks up the default dimensions of a spandrel element from the assignments made to the objects associated with the spandrel. You can revise the default dimensions in the spandrel design overwrites.

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 you can check the design thickness:

- Click the **Design menu > Shear Wall Design > Display Design Info** command, click the Design Input radio button 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.

ETABS assumes that the thickness it picks up from the first area object applies at both the left and right sides of the spandrel. Again, if you want something different at either the left or the right side you can revise 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 Chapter 9 for discussion of these 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 then the material property is taken from the first defined line object associated with the spandrel. There is no way for you as a user to know or tell which object area was defined first. Thus, if you have the condition where a spandrel is made up of different objects that have different material properties assigned to them, then you should 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 what you want. If it isn't, you can revise the material property in the spandrel design overwrites.

1997 UBC Shear Wall Design Preferences

General

The ETABS shear wall design preferences are basic properties that apply to all wall pier and/or spandrel elements. This chapter describes the 1997 UBC concrete shear wall design preferences. To access the shear wall preferences click the **Options menu > Preferences > Shear Wall Design** command.

Default values are provided for all shear wall design preference items. Thus it is not necessarily 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 preferences are presented in a table. There are four columns in the table. Each of these columns is described below.

- **Column 1 - Item:** This column includes the name of the preference item as it appears in ETABS. To save space in the dialog boxes these names are generally short. A more complete description of the item is given in column 4.

- **Column 2 - Possible Values:** This column lists the possible values that the associated preference item can have.
- **Column 3 - Default Value:** This column shows the default value that ETABS assumes for the associated preference item.
- **Column 4 - Description:** This column includes a description of the associated preference item.

Shear Wall Preferences

(Below) Table 8-1: *1997 UBC shear wall preferences*

Table 8-1 lists the 1997 UBC shear wall design preferences.

Item	Possible Values	Default Value	Description
Design Code	UBC97	UBC97	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 whether design load combinations that include a time history are 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, then that design load combination is designed for the envelopes of the time histories regardless of what is specified here.
phi-b	> 0	0.9	Strength reduction factor for bending in a wall pier or spandrel, ϕ_b. See Chapters 12 and 14.
phi-c	> 0	0.7	Strength reduction factor for axial compression in a wall pier, ϕ_c. See Chapter 12.

Item	Possible Values	Default Value	Description
phi-vns	> 0	0.85	Strength reduction factor for shear in a wall pier or spandrel for a nonseismic condition, ϕ_{vns}. See Chapters 13 and 15.
phi-vs	> 0	0.6	Strength reduction factor for shear in wall pier or spandrel for a seismic condition, ϕ_{vs}. See Chapters 13 and 15.
Pmax Factor	> 0	0.80	Factor used to reduce the allowable maximum compressive design strength. See the subsection titled "Formulation of the Interaction Surface" in Chapter 12.
Rebar units	in^2, cm^2, mm^2,current	in^2 or mm^2	Units used for concentrated areas of reinforcing steel. See the section titled "Units" in Chapter 5.
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 the section titled "Units" in Chapter 5.
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 the section titled "Interaction Surface" in Chapter 12.
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 the section titled "Interaction Surface" in Chapter 12.
Edge Design PC-max	> 0	0.04	Maximum ratio of compression reinforcing allowed in edge members, PC_{max}. See the subsection titled "Design Condition 1" in Chapter 12.
Edge Design PT-max	> 0	0.06	Maximum ratio of tension reinforcing allowed in edge members, PT_{max}. See the subsection titled "Design Condition 1" in Chapter 12.

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Item	Possible Values	Default Value	Description
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 Chapter 12.
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 Chapter 12.

(Above)
Table 8-1:
1997 UBC shear wall preferences

1997 UBC Shear Wall Design Overwrites

General

This chapter describes the 1997 UBC concrete shear wall design overwrites. The overwrites for piers and spandrels are separate. 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 it is not necessarily required that you specify or change any of the overwrites. You should however at least review the default values for the overwrite items to make sure they are acceptable to you. When you make changes to overwrite items ETABS only applies the changes to the elements that they are specifically assigned to, that is, to the elements that are selected when you change the overwrites.

See the section titled "Making Changes in the Overwrites Dialog Box" later in this chapter for important information on modifying the overwrites.

The overwrites are presented in tables. There are four columns in the table. Each of these columns is described below.

- **Column 1 - Item:** This column includes the name of the overwrite item as it appears in ETABS. To save space in the dialog boxes these names are generally short. A more complete description of the item is given in column 4.
- **Column 2 - Possible Values:** This column lists the possible values that the associated overwrite item can have.
- **Column 3 - Default Value:** This column shows the default value that ETABS assumes for the associated overwrite item.
- **Column 4 - Description:** This column includes a description of the associated overwrite item.

Pier Design Overwrites

(Below) Table 9-1: *1997 UBC pier design overwrites*

Table 9-1 lists the 1997 UBC pier design overwrites.

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Design this Pier	Yes or No	Yes	Toggle for whether ETABS should design 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 below titled "LL Reduction Factor" for more information.

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
EQ Factor	≥ 0	1	Multiplier on earthquake loads. If 0 is entered for this item then the program resets it to the default value of 1 when the next design is run. See the subsection below titled "EQ Factor" for more information.
Design is Seismic	Yes or No	Yes	Toggle for whether ETABS should consider the design as seismic or nonseismic. Additional design checks are done for seismic elements compared to nonseismic elements. Also in some cases the strength reduction factors are different.
Properties From	Simplified Section or Section Designer	Simplified Section	This item indicates the source of the design properties for the pier. The Section Designer option is not available unless pier sections have previously been defined in Section Designer. See the section titled "Analysis Sections versus Design Sections" in Chapter 5 and see Chapter 6 for more information.
Design Pier is 3D	Yes or No	No	Toggle for whether the design is two-dimensional or three-dimensional. If the Properties From item is Simplified Section then the Design Pier is 3D item can only be No, that is, the pier can only be designed two-dimensionally. This item only affects the shear design and boundary element check. The PMM flexural design is always 3D.
Section Bottom	Any 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. This item is only active if the Properties From item is set to Section Designer.

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Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Section Top	Any 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. This item is only active if the Properties From item is set to Section Designer.
V2 Length	Program calculated, > 0	Program calculated	Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction when a Section Designer section is assigned to the pier. This item is only active if the Properties From item is set to Section Designer. See the section titled "Section Designer Pier Effective Section for Shear" in Chapter 6 for more information. Inputting 0 means the item is to be program calculated.
V2 Thickness	Program calculated, > 0	Program calculated	Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction when a Section Designer section is assigned to the pier. This item is only active if the Properties From item is set to Section Designer. See the section titled "Section Designer Pier Effective Section for Shear" in Chapter 6 for more information. Inputting 0 means the item is to be program calculated.

Pier Over-write Item	Possible Values	Default Value	Pier Overwrite Description
V3 Length	Program cal-culated, > 0	Program cal-culated	Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction when a Section Designer section is assigned to the pier. This item is only active if the Properties From item is set to Section Designer and the Design Pier is 3D item is set to Yes. See the section titled "Section Designer Pier Effective Section for Shear" in Chapter 6 for more information. Inputting 0 means the item is to be program calculated.
V3 Thickness	Program cal-culated, > 0	Program cal-culated	Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction when a Section Designer section is assigned to the pier. This item is only active if the Properties From item is set to Section Designer and the Design Pier is 3D item is set to Yes. See the section titled "Section Designer Pier Effective Section for Shear" in Chapter 6 for more information. Inputting 0 means the item is to be program calculated.
ThickBot	Program cal-culated, or > 0	Program cal-culated	Wall pier thickness at bottom of pier, t_p. See Figure 6-1. This item is only active if the Properties From item is set to Simplified Section. See the subsection titled "How ETABS Calculates the Default Dimensions" in Chapter 6 for more information. Inputting 0 means the item is to be program calculated.

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
LengthBot	Program calculated, or > 0	Program calculated	Wall pier length at bottom of pier, L_p. See Figure 6-1. This item is only active if the Properties From item is set to Simplified Section. See the subsection titled "How ETABS Calculates the Default Dimensions" in Chapter 6 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 6-1. This item is only active if the Properties From item is set to Simplified Section. See the subsection below titled "User-Defined Edge Members" for more information.
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 6-1. This item is only active if the Properties From item is set to Simplified Section. See the subsection below titled "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 6-1. This item is only active if the Properties From item is set to Simplified Section. See the subsection below titled "User-Defined Edge Members" for more information.

Pier Over-write Item	Possible Values	Default Value	Pier Overwrite Description
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 6-1. This item is only active if the Properties From item is set to Simplified Section. See the subsection below titled "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 6-1. This item is only active if the Properties From item is set to Simplified Section. See the subsection titled "How ETABS Calculates the Default Dimensions" in Chapter 6 for more information. Inputting 0 means the item is to be program calculated.
LengthTop	Program calculated, or > 0	Program calculated	Wall pier length at top of pier, L_p. See Figure 6-1. This item is only active if the Properties From item is set to Simplified Section. See the subsection titled "How ETABS Calculates the Default Dimensions" in Chapter 6 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 6-1. This item is only active if the Properties From item is set to Simplified 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 6-1. This item is only active if the Properties From item is set to Simplified 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 6-1. This item is only active if the Properties From item is set to Simplified Section.

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
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 6-1. This item is only active if the Properties From item is set to Simplified Section.
Material	Any defined concrete material property	See the subsection titled "Material Properties" in Chapter 6	Material property associated with the pier. This item is only active if the Properties From item is set to Simplified Section.
Edge Design PC-max	> 0	Specified in Preferences	Maximum ratio of compression reinforcing allowed in edge members, PC_{max}. See the section titled "Design Condition 1" in Chapter 12. This item is only active if the Properties From item is set to Simplified Section.
Edge Design PT-max	> 0	Specified in Preferences	Maximum ratio of tension reinforcing allowed in edge members, PT_{max}. See the section titled "Design Condition 1" in Chapter 12. This item is only active if the Properties From item is set to Simplified Section.

(Above) Table 9-1: *1997 UBC pier design overwrites*

LL Reduction Factor

If the LL Reduction Factor is program calculated then 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 then ETABS 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, suppose you have two static load cases labeled DL and RLL. DL is a dead load and RLL is a reducible live load.

Now suppose 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 suppose 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. Then 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, suppose you have two static load cases labeled DL and EQ. DL is a dead load and EQ is a quake load.

Now suppose that you create a design load combination named DESCOMB1 that includes DL and EQ. Then for design load combination DESCOMB1 the EQ load is multiplied by the EQ factor.

Next suppose 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. Then 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 then the edge member width is taken the same as the pier thickness and the edge member length is determined by ETABS.

Spandrel Design Overwrites

(Below) Table 9-2: *1997 UBC spandrel design overwrites*

Table 9-2 lists the 1997 UBC spandrel design overwrites.

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Design this Spandrel	Yes or No	Yes	Toggle for whether ETABS should design the spandrel when you click the **Design menu > Shear Wall Design > Start Design/Check of Structure** command.

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
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 above titled "LL Reduction Factor" for more information.
EQ Factor	≥ 0	1	Multiplier on earthquake loads. If 0 is entered for this item then the program resets it to the default value of 1 when the next design is run. See the previous subsection titled "EQ Factor" for more information.
Design is Seismic	Yes or No	Yes	Toggle for whether ETABS should consider the design as seismic or non-seismic. Additional design checks are done 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 7-1. Inputting 0 means the item is to be program calculated.
ThickLeft	Program calculated, or > 0	Program calculated	Wall spandrel thickness at left side of spandrel, t_s. See Figure 7-1. 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 7-1. 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 7-1. Inputting 0 means the item is to be program calculated as $0.1h_s$.

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Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
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 7-1. 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 7-1.
SlabDepthLeft	≥ 0	0	Slab depth for T-beam at left end of spandrel, d_s. See Figure 7-1.
ThickRight	Program calculated, or > 0	Program calculated	Wall spandrel thickness at right side of spandrel, t_s. See Figure 7-1. 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 7-1. 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 7-1. Inputting 0 means the item is to be program calculated as $0.1h_s$.
CoverTopRight	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 7-1. Inputting 0 means the item is to be program calculated as $0.1h_s$.
SlabWidthRight	≥ 0	0	Slab width for T-beam at right end of spandrel, b_s. See Figure 7-1.
SlabDepthRight	≥ 0	0	Slab depth for T-beam at right end of spandrel, d_s. See Figure 7-1.
Material	Any defined concrete material property	See the section titled "Default Design Material Property" in Chapter 7	Material property associated with the spandrel.

Pier Overwrite Item	Possible Values	Default Value	Pier Overwrite Description
Consider Vc	Yes or No	Yes	Toggle switch for whether to consider V_c (concrete shear capacity) when computing the shear capacity of the spandrel.

(Above)
Table 9-2:
1997 UBC spandrel design overwrites

Making Changes in the Overwrites Dialog Box

When you view the pier or spandrel overwrites you see a column of check boxes on the left side of the dialog box next to a two-column spreadsheet. The left column in the spreadsheet contains the name of the overwrite item. The right column in the spreadsheet contains the overwrite value.

When you first enter the Composite Beam Overwrites dialog box the check boxes are all unchecked and all of the cells in the spreadsheet have a gray background to indicate they are inactive and that the items in the cells can not currently be changed. The names of the overwrite items in the first column of the spreadsheet are visible. The values of the overwrite items in the second column of the spreadsheet are visible if only one pier or spandrel is selected when you enter the overwrites dialog box. If multiple piers or spandrels are selected when you enter the dialog box then no values show for the overwrite items in the second column of the spreadsheet.

Whether you have selected one or multiple piers or spandrels, to change an overwrite item first check the box to the left of the item to indicate that you want to change it. When you check this box the associated cell in the second column of the spreadsheet becomes active. Left click in this cell and either a drop-down box with several selections appears or you simply see the current item in the cell highlighted. If the drop-down box appears then select a value from the box. Otherwise type in whatever value you desire.

When you finish making changes to the pier or spandrel overwrites click the **OK** button to close the dialog box. ETABS 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 ETABS. If you click the **Cancel** button to exit the dialog box then any changes you made to the overwrites are ignored and the dialog box is closed.

1997 UBC Design Load Combinations

This chapter defines the default 1997 UBC concrete shear wall design load combinations. You may use the default shear wall design load combinations for your design, or you may define your own design load combinations, or you can use both default combinations and your own combinations. You can modify the default design load combinations and you can delete them if you wish.

Default Design Load Combinations

The ETABS automatically created design load combinations for concrete shear wall design based on the 1997 UBC are given by Equations 10-1 through 10-10.

$$1.4\Sigma DL \quad \text{Eqn. 10-1}$$

$$1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL) \quad \text{Eqn. 10-2}$$

Note:

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

$0.75[1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL) + 1.7WL]$ Eqn. 10-3

$0.75[1.4\Sigma DL + 1.7(\Sigma LL + \Sigma RLL) - 1.7WL]$ Eqn. 10-4

$0.9\Sigma DL + 1.3WL$ Eqn. 10-5

$0.9\Sigma DL - 1.3WL$ Eqn. 10-6

$1.1\ [1.2\Sigma DL + 0.5(\Sigma LL + \Sigma RLL) + 1.0E]$ Eqn. 10-7

$1.1\ [1.2\Sigma DL + 0.5(\Sigma LL + \Sigma RLL) - 1.0E]$ Eqn. 10-8

$1.1\ (0.9\Sigma DL + 1.0E)$ Eqn. 10-9

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

In Equations 10-1 through 10-10,

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 times the specified factor. Individual dead load cases are not considered separately in the default design load combinations.

See the discussion of the earthquake load component below for additional information on this topic.

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 times 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 there are multiple wind load cases defined in the ETABS 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 there are multiple earthquake load cases defined in the ETABS model, each of Equations 10-7 through 10-10 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.

The reliability/redundancy factor, ρ, that is given in Equation 30-1 of Section 1630.1.1 of the 1997 UBC is not specifically considered by ETABS, and should be included by the user in user-defined load combinations, as necessary. You can use the Horizontal EQ Factor that is available in the overwrites for this purpose.

Note that ETABS also does not include any affect of E_v given in Equation 30-1 of Section 1630.1.1 of the 1997 UBC. The user should account for this affect, if necessary, in the multiplier on the dead load in the user-defined load combinations.

Design Load Combinations that Include a Response Spectrum

In ETABS 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 ETABS 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 there are four possible combinations considered for the contribution of response spectrum load to the design load combination. They are:

Note:

Any ETABS 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.

- +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 there are eight possible combinations of P, M2 and M3 considered for three-dimensional wall piers.

Note that based on the above, Equations 10-7 and 10-8 are redundant for a load combination with a response spectrum and similarly Equations 10-9 and 10-10 are redundant for a load combination with a response spectrum. For this reason, ETABS only creates default design load combinations based on Equations 10-7 and 10-9 for response spectra. Default design load combinations using Equations 10-8 and 10-10 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. If you want to include time history forces in a design load combination then you must define the load combination yourself.

Note:

Designing for each step of a time history can be very time consuming.

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 Chapter 8 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 real 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 can be very time consuming.

When ETABS 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 ETABS 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 there are four possible combinations 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 then 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. If you want to include static nonlinear results in a design load combination then you must define the load combination yourself.

If a design load combination includes a single static nonlinear case and nothing else, then 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.

Chapter 11

11

1997 UBC Wall Pier Boundary Elements

This chapter discusses how ETABS considers the boundary element requirements for concrete wall piers using the 1997 UBC. ETABS uses an approach based on the requirements of Section 1921.6.6.4 in the 1997 UBC.

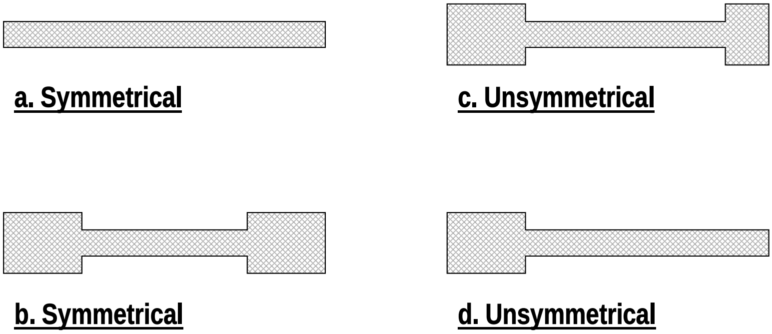
Note that the boundary element requirements are considered separately for each design load case that includes seismic load.

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 6-1 in Chapter 6 for an illustration of the dimensions L_p and t_p.

Figure 11-1: *Example plan views of symmetrical and unsymmetrical wall piers*



Note:

ETABS only considers 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 ETABS.

- 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.
- Whether the wall pier is symmetrical or unsymmetrical, that is, 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 11-1 shows some examples of symmetrical and unsymmetrical wall piers. Note that a pier defined in Section Designer is assumed to be unsymmetrical unless it is made up of a single rectangular shape.

Note:

For simplified design only, if there is a flexural failure in any design load combination, then ETABS sets A_s in Eqn. 11-1 to zero for all design load combinations considered for the pier.

Using this information ETABS calculates the value of P_O which is the nominal axial load strength of the wall using Equation 11-1.

$$P_O = 0.85f'_c\,(A_g - A_s) + f_y A_s \qquad \text{Eqn. 11-1}$$

Once the value of P_O is known ETABS calculates four quantities which are used to determine the boundary zone requirements. These quantities are:

- $\dfrac{P_u}{P_O}$
- $\dfrac{P_u}{A_g f'_c}$

Figure 11-2:
Flowchart of process ETABS uses to determine if boundary elements are required

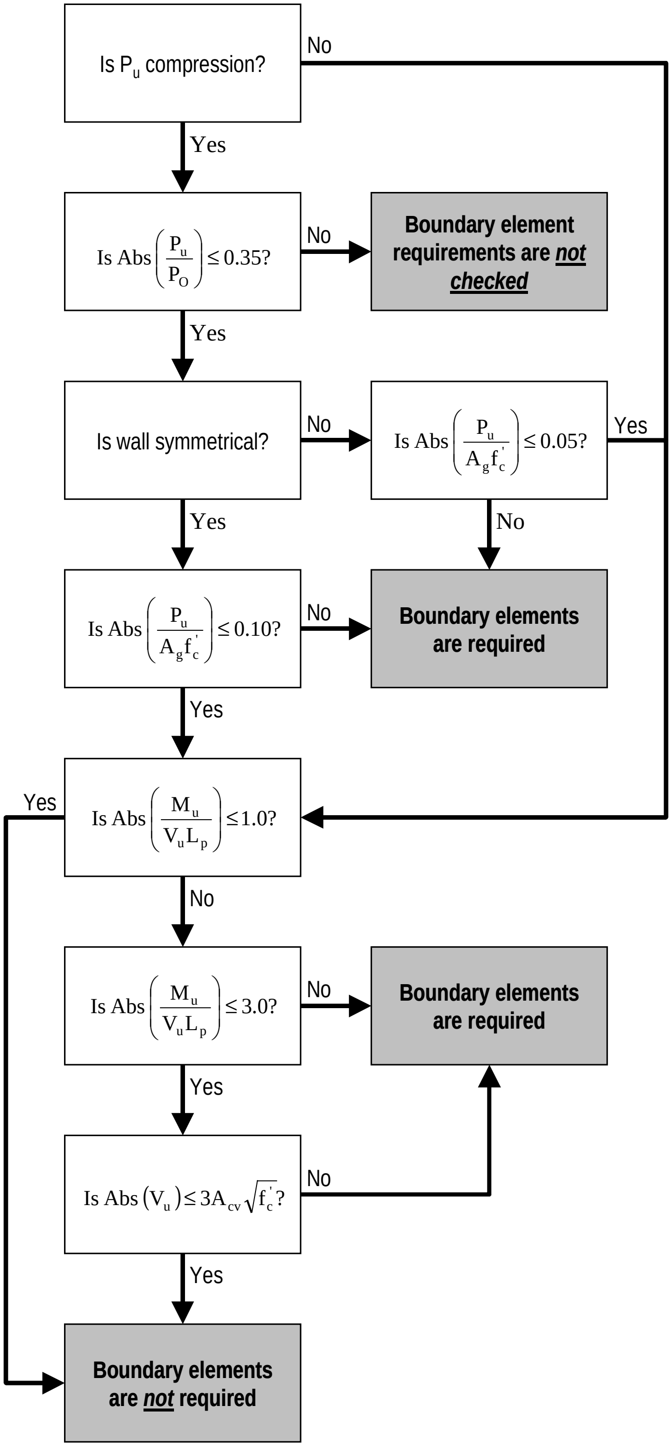
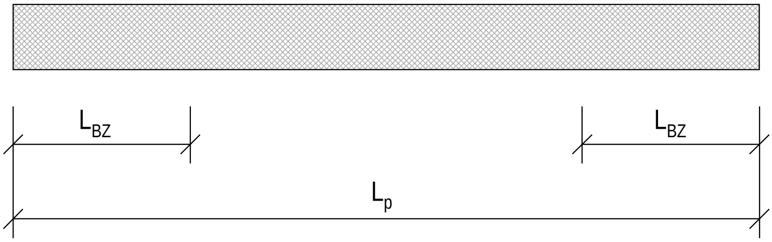


Figure 11-3:
Illustration of boundary zone length, L_{BZ}



- $\frac{M_u}{V_u L_p}$
- $3A_{cv}\sqrt{f'_c}$

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The flowchart in Figure 11-2 illustrates the process ETABS uses to determine if boundary elements are required. Note that if P_u exceeds 0.35 P_O then the boundary element requirements are not checked. This is based on 1997 UBC Section 1921.6.6.3.

If boundary elements are required then ETABS 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 ETABS calculates L_{BZ} using either Equation 11-2a or 11-2b depending on whether P_u is compression or tension.

When P_u is compression:

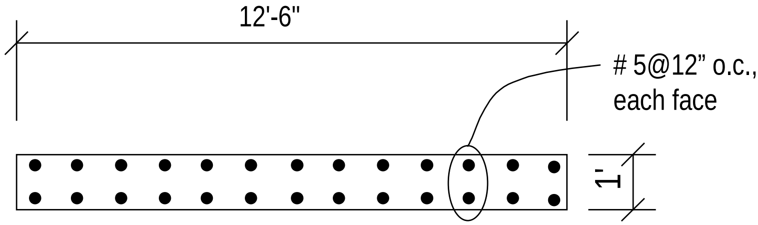
$$L_{BZ} = \left[\text{Abs}\left(\frac{P_u}{2P_O}\right) + 0.075 \right] L_p \geq 0.15L_p \qquad \text{Eqn. 11-2a}$$

When P_u is tension:

$$L_{BZ} = 0.15L_p \qquad \text{Eqn. 11-2b}$$

Figure 11-3 illustrates the boundary zone length L_{BZ}.

Figure 11-4:
Wall pier for example calculations



f'c = 4 ksi
fy = 60 ksi

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

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Example

Figure 11-4 shows the 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.

The calculations follow:

P_u = 1000 kips (given)

L_p = 12.5 feet = 150 inches (given)

$A_g = 12.5\text{ ft} * 1\text{ ft} = 12.5\text{ ft}^2 = 1800\text{ in}^2$

$A_s = 13\text{ bars} * 2\text{ faces} * 0.31\text{ in}^2 = 8.06\text{ in}^2$

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 (1800 - 8.06) + 60 * 8.06 = 6576 kips

$$\frac{P_u}{P_O} = \frac{1000}{6576} = 0.152 < 0.35 \quad \underline{\textbf{OK}}$$

Note:

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

$$\frac{P_u}{A_g f_c^{'}} = \frac{1000}{1800 * 4} = 0.139 > 0.1 \quad \underline{\textbf{NG}}$$

Therefore boundary elements are required.

$$L_{BZ} = \left(\frac{1000}{2 * 6576} + 0.075 \right) * 150 = 22.7 \text{ inches}$$

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1997 UBC Wall Pier Flexural Design

Overview

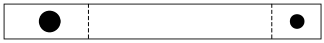
This chapter discusses how ETABS designs and checks concrete wall piers for flexural and axial loads using the 1997 UBC. The chapter is broken into three main sections. First it describes how ETABS *designs* piers that are specified by a Simplified Section. Next it discusses how ETABS *checks* piers that are specified by a Section Designer Section. Finally it describes how ETABS *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. This is described in the ETABS User's Manual.

Designing a Simplified Pier Section

This section discusses how ETABS designs a pier that is assigned a simplified section. The geometry associated with the simplified section is illustrated in the section titled "Simplified

Figure 12-1: *Design conditions for simplified wall piers*



Design Condition 1

Wall pier with uniform thickness and ETABS-determined (variable length) edge members

Design Condition 2

Wall pier with user-defined edge members

Design Condition 3

Wall pier with a user-defined edge member on one end and an ETABS-determined (variable length) edge member on the other end

Note:

In all three conditions, the only reinforcing designed by ETABS is that required at the center of the edge members

Pier Design Dimensions and Properties" in Chapter 6. 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 are specified by you then ETABS assumes that the edge member is the same width as the wall and it determines the required length of the edge member. In all cases, whether the edge member size is user-specified or ETABS-determined, ETABS reports the required area of reinforcing steel at the center of the edge member. This section describes how the ETABS-determined length of the edge member is determined and how ETABS calculates the required reinforcing at the center of the edge member.

There are three possible design conditions for a simplified wall pier. These conditions, illustrated in Figure 12-1, are:

1. The wall pier has ETABS-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 an ETABS-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 ETABS-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 12-2. For a given design section, say the top of the wall pier, for a given design load combination, the wall pier is designed for a factored axial force $P_{u\text{-}top}$ and a factored moment $M_{u\text{-}top}$.

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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 12-1a and 12-1b. (Similar equations apply at the bottom of the pier).

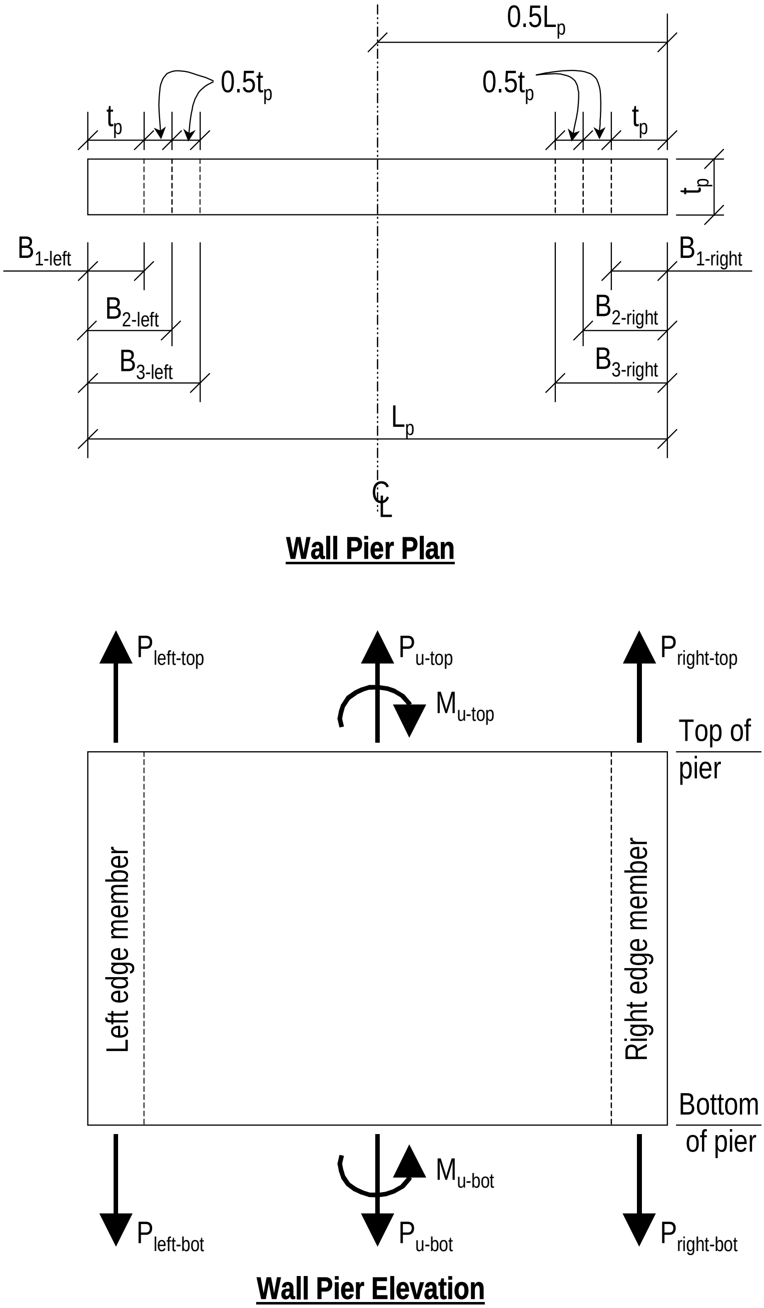
$$P_{left-top} = \frac{P_{u-top}}{2} + \frac{M_{u-top}}{\left(L_p - 0.5B_{1-left} - 0.5B_{1-right}\right)} \qquad \text{Eqn. 12-1a}$$

$$P_{right-top} = \frac{P_{u-top}}{2} - \frac{M_{u-top}}{\left(L_p - 0.5B_{1-left} - 0.5B_{1-right}\right)} \qquad \text{Eqn. 12-1b}$$

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.

Figure 12-2:
Wall pier for design condition 1



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

$$A_{st} = \frac{P}{\phi_b f_y} \qquad \text{Eqn. 12-2}$$

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

$$\text{Abs}(P) = (\text{Pmax Factor})\,\phi_c\,[0.85f'_c(A_g - A_{sc}) + f_y A_{sc}] \qquad \text{Eqn. 12-3}$$

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 12-3,

$$A_{sc} = \frac{\dfrac{\text{Abs}(P)}{(\text{Pmax Factor})\,\varphi_c} - 0.85f'_c A_g}{f_y - 0.85f'_c} \qquad \text{Eqn. 12-4}$$

If A_{sc} calculates as negative then 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:

$$A_{st\text{-}max} = PT_{max} t_p B_1 \qquad \text{Eqn. 12-5}$$

Similarly, the compression reinforcing is limited by:

$$A_{sc\text{-}max} = PC_{max} t_p B_1 \qquad \text{Eqn. 12-6}$$

If A_{st} is less than or equal to $A_{st\text{-}max}$ and A_{sc} is less than or equal to $A_{sc\text{-}max}$ then ETABS 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.

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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, ETABS 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 (ETABS-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 Section Designer Pier Section

When you specify that a Section Designer pier section is to be checked, ETABS 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 ETABS generates the interaction surface for the pier and how it determines the demand/capacity ratio for a given design load combination.

Interaction Surface

General

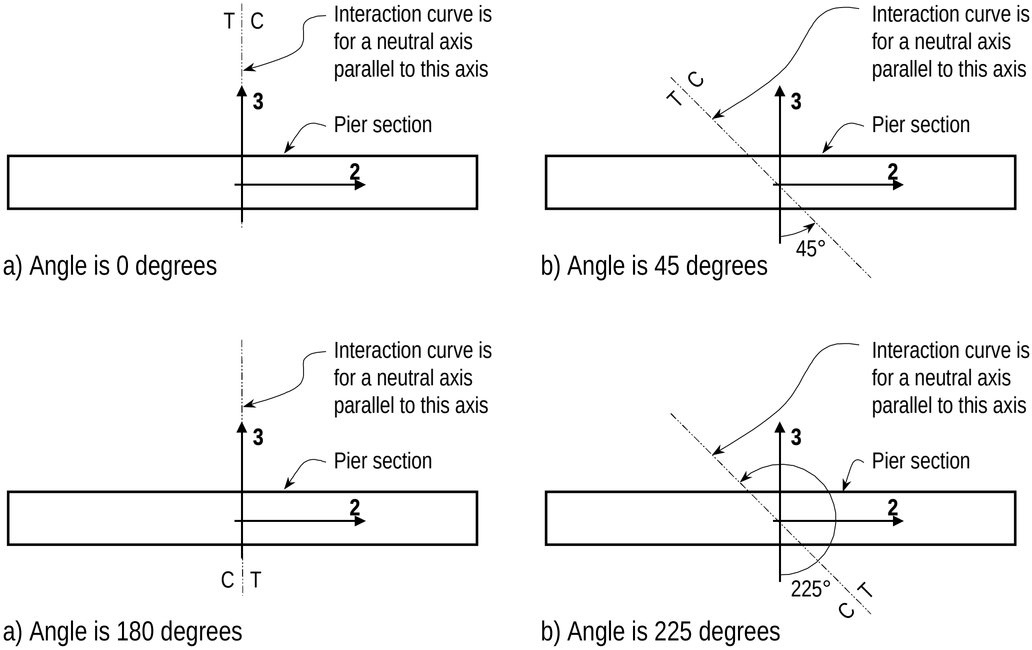
Note:

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

In ETABS a three-dimensional interaction surface is defined referenced to the P, M2 and M3 axes by a series of PMM 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) then there is one curve every 360°/24 curves = 15°. Figure 12-3 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 chapter in the subsection titled "Details of the Strain Compatibility Analysis".



(Above)
Figure 12-3:
Orientation of the pier neutral axis for various angles

By default 11 points are used to define a PMM interaction curve. You can change this number in the preferences where you can specify 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 in the preferences it will be incremented up to the next odd number by ETABS.

Note that when creating an interaction surface for a two-dimensional wall pier, ETABS only considers 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 ETABS is based consistently on the basic principles of ultimate strength design given in Sections 1910.2 and 1910.3 of the 1997 UBC.

ETABS 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 12-7.

$$(P_u, M2_u, M3_u) \le (\phi P_n, \phi M2_n, \phi M3_n) \qquad \text{Eqn. 12-7}$$

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:

Note:

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

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.

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.

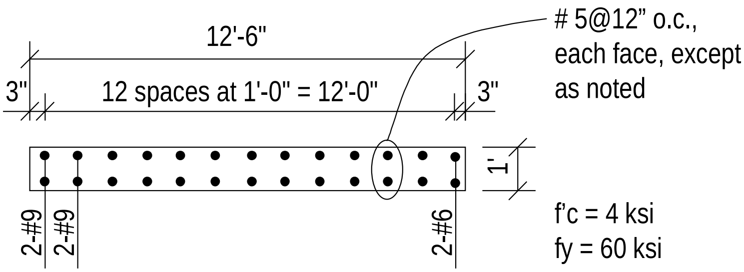
The theoretical maximum compressive force the wall pier can carry, assuming the ϕ_c factor is equal to 1 is called P_{oc} and is given by Equation 12-8.

$$P_{oc} = [0.85f'_c\,(A_g - A_s) + f_yA_s] \qquad \text{Eqn. 12-8}$$

The theoretical maximum tension force the wall pier can carry, assuming the ϕ_b factor is equal to 1 is called P_{ot} and is given by Equation 12-9.

$$P_{ot} = f_yA_s \qquad \text{Eqn. 12-9}$$

Figure 12-4: *Example two-dimensional wall pier with unsymmetrical reinforcing*



If the wall pier geometry and reinforcing is symmetrical in plan then 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, $\phi_c P_n$, to the value given by P_{max} in Equation 12-10.

$$P_{max} = 0.80\phi_c P_{oc} = 0.80\phi[0.85f'_c (A_g - A_s) + f_y A_s] \quad \text{Eqn. 12-10}$$

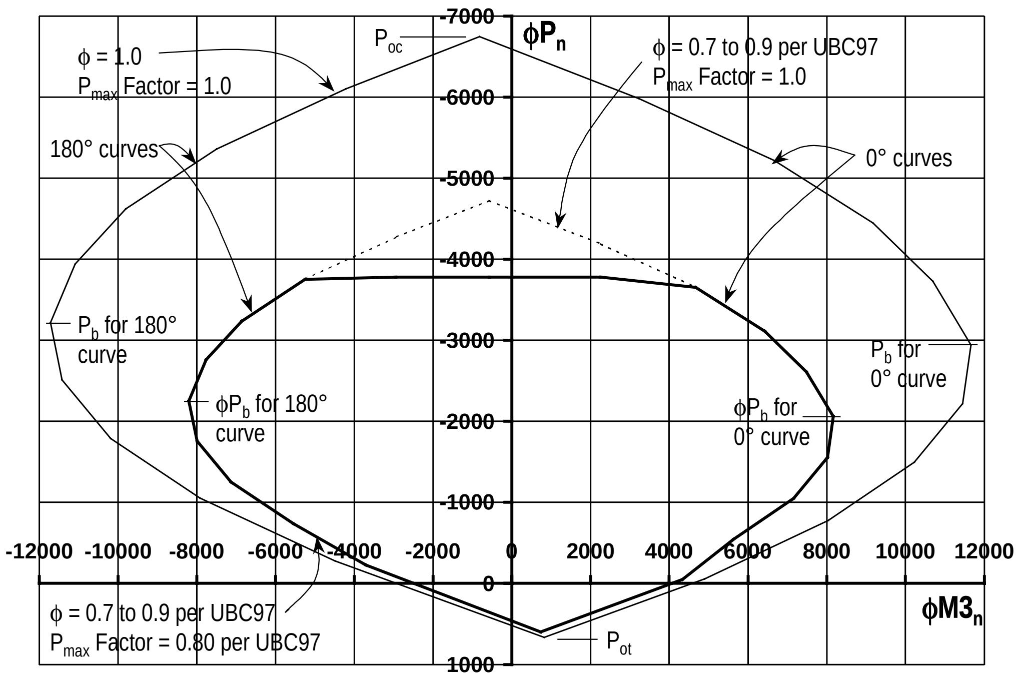
Note that the equation defining P_{max} reduces P_{oc} not only by a strength reduction factor, ϕ_c, but also by an additional factor of 0.80. In the preferences this factor is called the Pmax Factor and you can specify different values for it if desired. In all 1997 UBC code designs it is prudent to 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 ETABS 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 12-4 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 12-5 shows several interaction surfaces for the wall pier illustrated in Figure 12-4. Note the following about Figure 12-5:

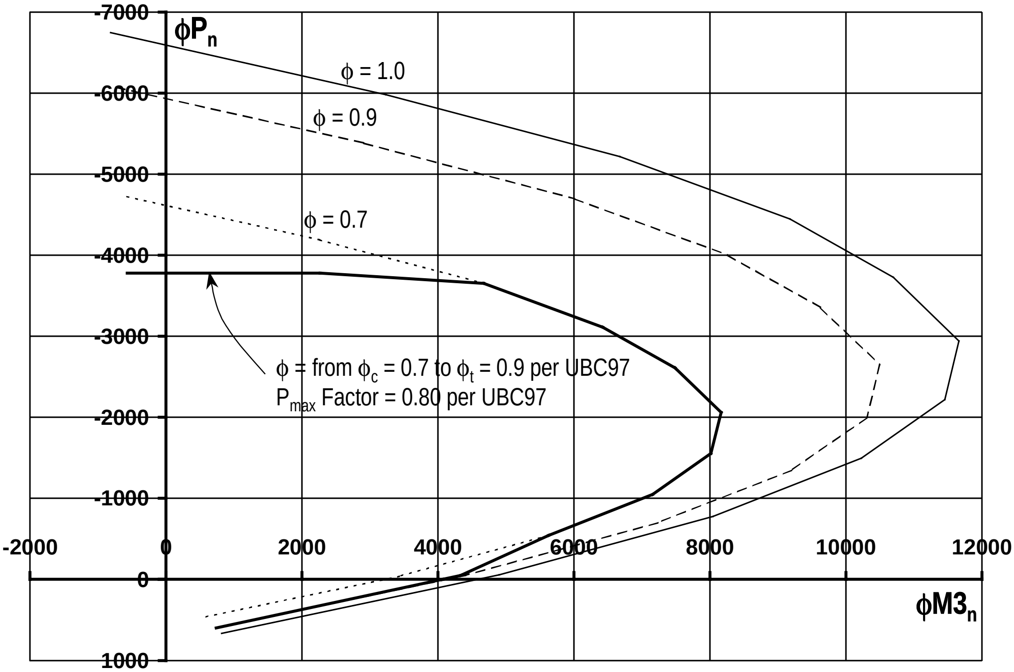


(Above)
Figure 12-5:
Interaction curves for example wall pier shown in Figure 12-4

- Since 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 since this is a two-dimensional example.
- In ETABS 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.

Note:

In ETABS tension is positive and compression is negative.



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(Above)
Figure 12-6:
Interaction curves for example wall pier shown in Figure 12-4

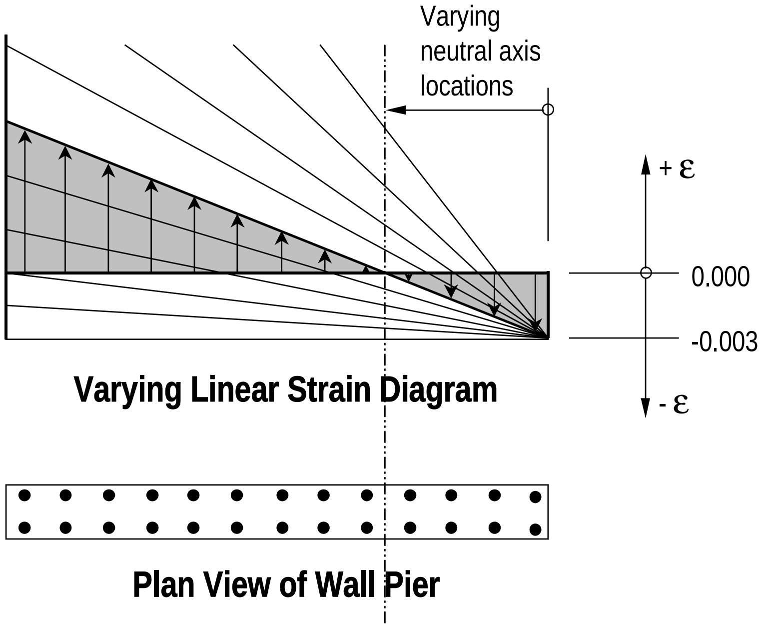
- The interaction surfaces shown are created using the default value of 11 points for each interaction curve.

Figure 12-6 shows the 0° interaction curves for the wall pier illustrated in Figure 12-4. Additional interaction curves are also added to Figure 12-6. The smaller, heavier curve in Figure 12-6 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 give you more of a sense of how ETABS 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, ETABS 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.

Figure 12-7:
Varying planes of linear strain



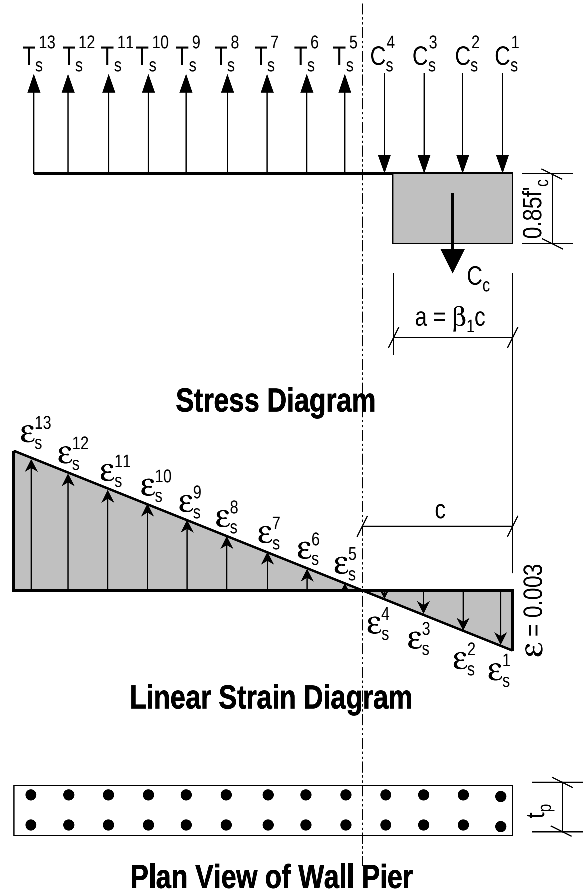
The coordinates of these points are determined by rotating a plane of linear strain on the section of the wall pier.

Figure 12-7 illustrates varying planes of linear strain such as those that ETABS 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 ETABS 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) then P_b is obtained.

Figure 12-8 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 12-7.

In Figure 12-8 the compressive stress in the concrete, C_c, is calculated using Equation 12-11.

Figure 12-8:
Wall pier stress-strain relationship



$$C_c = 0.85f'_c\beta_1 ct_p \qquad \text{Eqn. 12-11}$$

In Figure 12-7 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 12-12 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.

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

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The force in the reinforcing steel (T_s for tension or C_s for compression) is calculated using Equation 12-13 where:

$$T_s \text{ or } C_s = \sigma_s A_s \qquad \text{Eqn. 12-13}$$

For the given distribution of strain the value of ϕP_n is calculated using Equation 12-14.

$$\phi P_n = \phi(\Sigma T_s - C_c - \Sigma C_s) \leq P_{max} \qquad \text{Eqn. 12-14}$$

In Equation 12-14 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 12-10.

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.

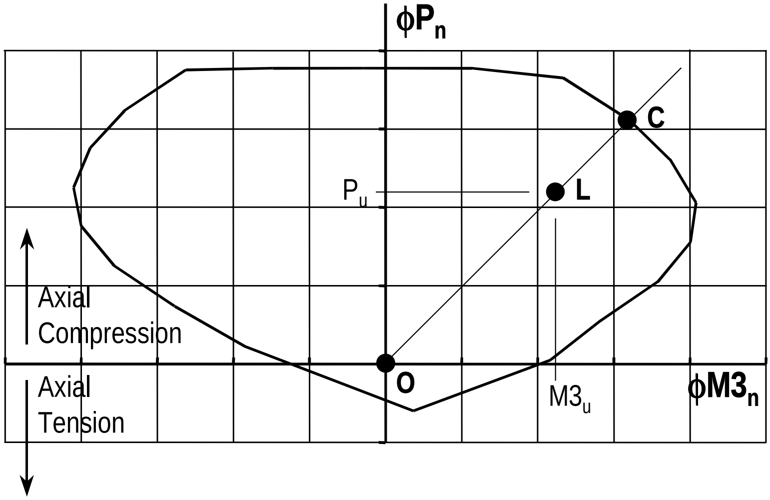
When one interaction curve is complete the next orientation of the neutral axis is assumed and the points for the associated new interaction curve are calculated. This process continues until the points for all of the specified curves have been calculated.

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

Wall Pier Demand/Capacity Ratio

Refer to Figure 12-9 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 then the wall

Figure 12-9: Two-dimensional wall pier demand/capacity ratio



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 a stress ratio is calculated. 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:

Note:

The process used for checking the demand/capacity ratio of three-dimensional piers is similar to that described here for two- dimensional piers.

- 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 Section Designer Pier Section

When you specify that a Section Designer pier section is to be designed, ETABS 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 in between. The spacing between the reinforcing ratios is calculated as an increasing arithmetic series where the space between the first two ratios is equal to one-third of the space between the last two ratios.

Table 12-1 illustrates the spacing both in general terms and for a specific example where the minimum reinforcing ratio, IPmin, is 0.0025 and the maximum, IPmax, is 0.02.

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Table 12-1:
The eight reinforcing ratios used by ETABS

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

Once the eight reinforcing ratios are determined ETABS develops interaction surfaces for all eight of the ratios using the process described earlier in this chapter in the section titled "Checking a Section Designer Pier Section."

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

Chapter 13

13

1997 UBC Wall Pier Shear Design

This chapter discusses how ETABS designs concrete wall piers for shear using the 1997 UBC. Note that in ETABS you can not specify shear reinforcing and then have ETABS check it. ETABS 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.

The first step above needs no further explanation. The following two sections describe in detail the algorithms associated with the last two above-mentioned steps.

Determine the Concrete Shear Capacity

Note:

The term R_{LW} that used as a multiplier on all $\sqrt{f'_c}$ terms in this chapter 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.

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 13-1 and 13-2.

$$V_c = 3.3 R_{LW} \sqrt{f'_c}\ t_p (0.8 L_p) - \frac{P_u (0.8 L_p)}{4 L_p} \qquad \text{Eqn. 13-1}$$

where V_c may not be greater than

$$V_c = \left[0.6 R_{LW} \sqrt{f'_c} + \frac{L_p \left(1.25 R_{LW} \sqrt{f'_c} - 0.2 \frac{P_u}{L_p t_p} \right)}{\text{Abs}\left(\frac{M_u}{V_u} \right) - \frac{L_p}{2}} \right] t_p (0.8 L_p) \qquad \text{Eqn. 13-2}$$

Equation 13-2 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 13-1 or Equation 13-2 results in a negative number then 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 chapter 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 ETABS tension is positive, thus the negative sign on the second term in Equation 13-1 is consistent with Equation

11-31 in the 1997 UBC. Similarly the negative sign on the second term in the parenthesis of Equation 13-2 is consistent with Equation 11-32 in the 1997 UBC.

Determine the Required Shear Reinforcing

Seismic and Nonseismic Piers

Given V_u and V_c, 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) is given by Equation 13-3. Note that additional requirements for seismic piers are given later in this section.

Note:

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

$$A_v = \frac{\dfrac{Abs(V_u)}{\phi} - V_c}{f_{ys}\ (0.8L_p)} \qquad \text{Eqn. 13-3}$$

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.

Note:

A pier is specified as seismic or nonseismic in the shear wall design overwrites.

In Equation 13-3 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.

Note:

The phi (ϕ) factors are set in the shear wall design preferences.

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

$$V_n = \left(2R_{LW}\sqrt{f'_c} + \frac{A_v}{t_p} f_{ys}\right) L_p t_p \qquad \text{Eqn. 13-4}$$

where,

$V_n = \dfrac{Abs\,(V_u)}{\phi_{vs}}$ must not exceed $8R_{LW}\sqrt{f'_c}\;t_pL_p$ 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 13-4 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 13-5.

$$A_v = \frac{\dfrac{Abs\,(V_u)}{\phi_{vs}} - 2R_{LW}\sqrt{f'_c}\;L_pt_p}{f_{ys}L_p} \qquad \text{Eqn. 13-5}$$

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Note that ETABS 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 ETABS to $8R_{LW}\sqrt{f'_c}\;t_pL_p$ not $10R_{LW}\sqrt{f'_c}\;t_pL_p$.

Chapter 14

14

1997 UBC Spandrel Flexural Design

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

General

Note:

ETABS allows both rectangular and T-beam sections for spandrels.

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

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.

Determining 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. 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

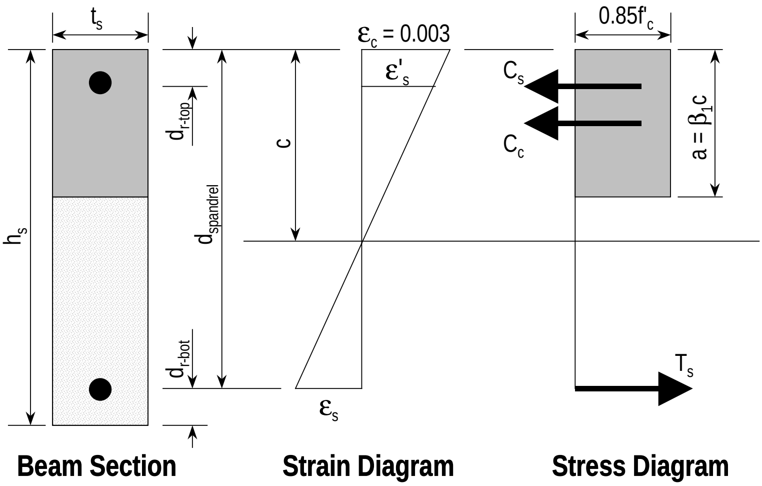
In ETABS negative beam moments produce top steel. In such cases the beam is always designed as a rectangular section.

In ETABS 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 14-1. Furthermore, 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 this 0.75 times the balanced condition, an area of compression reinforcement is calculated on the assumption that the additional moment is carried by compression reinforcing and additional tension reinforcing.

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

Figure 14-1: *Rectangular spandrel beam design, positive moment*



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Rectangular Beam Flexural Reinforcing

Refer to Figure 14-1. 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 14-1.

$$M_u = C_c \left(d_{spandrel} - \frac{a}{2} \right) \qquad \text{Eqn. 14-1}$$

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 14-1 can be solved for the depth of the compression block, a, yielding Equation 14-2.

$$a = d_{spandrel} - \sqrt{d^2_{spandrel} - \frac{2M_u}{0.85f'_c\ \phi_b\ t_s}} \qquad \text{Eqn. 14-2}$$

ETABS uses Equation 14-2 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

$$\beta_1 = 0.85 - \frac{0.05\left(f'_c - 4000\right)}{1000} \qquad \text{Eqn. 14-3}$$

with a maximum of 0.85 and a minimum of 0.65, and c_b, the distance from the extreme compression fiber to the neutral axis for balanced strain conditions is given by Equation 14-4.

$$c_b = \frac{87000}{87000 + f_y} d_{spandrel} \qquad \text{Eqn. 14-4}$$

Tension Reinforcing Only Required

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Note:

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

If $a \le 0.75\beta_1 c_b$ then no compression reinforcing is required and ETABS calculates the area of tension reinforcing using Equation 14-5.

$$A_s = \frac{M_u}{\phi_b f_y \left(d_{spandrel} - \frac{a}{2}\right)} \qquad \text{Eqn. 14-5}$$

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

Tension and Compression Reinforcing Required

If $a > 0.75\beta_1 c_b$ then compression reinforcing is required and ETABS 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 14-6.

$$C_c = 0.85 f'_c a_b t_s \qquad \text{Eqn. 14-6}$$

The moment resisted by the couple between the concrete in compression and the tension steel, M_{uc}, is given by Equation 14-7.

$$M_{uc} = \phi_b C_c \left(d_{spandrel} - \frac{a_b}{2}\right) \qquad \text{Eqn. 14-7}$$

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

$$M_{us} = M_u - M_{uc} \qquad \text{Eqn. 14-8}$$

Note:

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

The force carried by the compression steel, C_s, is given by Equation 14-9.

$$C_s = \frac{M_{us}}{d_{spandrel} - d_r} \qquad \text{Eqn. 14-9}$$

Referring to Figure 14-1, the strain in the compression steel, ε'_s, is given by Equation 14-10.

$$\varepsilon_s' = \frac{0.003\left(c - d_r\right)}{c} \qquad \text{Eqn. 14-10}$$

The stress in the compression steel, f'_s, is given by Equation 14-11.

$$f_s' = E_s \varepsilon_s' = \frac{0.003E_s\left(c - d_r\right)}{c} \qquad \text{Eqn. 14-11}$$

The term d_r in Equations 14-9, 14-10 and 14-11 is equal to $d_{r\text{-}top}$ for positive bending and equal to $d_{r\text{-}bot}$ for negative bending. In Equations 14-10 and 14-11 the term c is equal to a_b/β_1.

The total required area of compression steel, A'_s; is calculated using Equation 14-12.

$$A_s' = \frac{C_s}{\phi_b (f_s' - 0.85f_c')} \qquad \text{Eqn. 14-12}$$

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

$$A_{sw} = \frac{M_{uc}}{\phi_b f_y \left(d_{spandrel} - \frac{a_b}{2}\right)} \qquad \text{Eqn. 14-13}$$

Note that Equation 14-13 is similar to Equation 14-5 that is used when only tension reinforcing is required.

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

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

In Equations 14-13 and 14-14 $d_{spandrel}$ is equal to h_s - $d_{r\text{-}bot}$ for positive bending and h_s - $d_{r\text{-}top}$ for negative bending. In Equation 14-14 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 14-15.

$$A_s = A_{sw} + A_{sc} \quad \text{Eqn. 14-15}$$

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

Thus the total tension reinforcement, A_s, is given by Equation 14-15 and the total compression reinforcement, A'_s, is given by Equation 14-12. 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 subsection 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 14-2. The method for calculating the required reinforcing steel depends on whether the compression block depth, a, calculated using Equation 14-2 falls within the depth of the T-beam flange, d_s. See Figure 14-2.

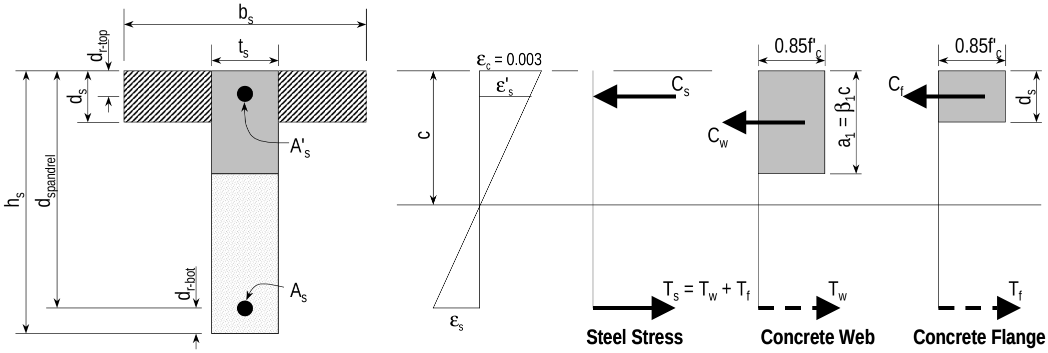

Figure 14-2: *Design of a wall spandrel with a T-beam section, positive moment*

- **If $a \leq d_s$**, the subsequent calculations for the reinforcing steel are exactly the same as previously defined for rectangular section design. However, in this 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 14-3 and 14-4, respectively.

- **If $a > d_s$**, the subsequent calculations for the required area of reinforcing steel are done 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.

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

Refer to Figure 14-2. The compression force in the protruding portion of the flange, C_f, is given by Equation 14-16. The protruding portion of the flange is shown cross-hatched.

$$C_f = 0.85f'_c (b_s - t_s)d_s \qquad \text{Eqn. 14-16}$$

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

$$A_{sf} = \frac{C_f}{f_y} \qquad \text{Eqn. 14-17}$$

Note:

T-beam action is only considered for positive moment.

The portion of the total moment, M_u, that is resisted by the flange, M_{uf}, is given by Equation 14-18.

$$M_{uf} = \phi_b C_f \left(d_{spandrel} - \frac{d_s}{2} \right) \qquad \text{Eqn. 14-18}$$

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

$$M_{uw} = M_u - M_{uf} \qquad \text{Eqn. 14-19}$$

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:

$$a_1 = d_{spandrel} - \sqrt{d_{spandrel}^2 - \frac{2M_{uw}}{0.85 f'_c \, \phi_b \, t_s}} \qquad \text{Eqn. 14-20}$$

Tension Reinforcing Only Required

If $a_1 \le 0.75\beta_1 c_b$, where β_1 and c_b are calculated from Equations 14-3 and 14-4, respectively, then no compression reinforcing is required and ETABS calculates the area of tension steel for balancing the compression force in the concrete web, A_{sw}, using Equation 14-21.

$$A_{sw} = \frac{M_{uw}}{\phi_b f_y \left(d_{spandrel} - \frac{a_1}{2} \right)} \qquad \text{Eqn. 14-21}$$

The total tension reinforcement A_s is given by Equation 14-22.

$$A_s = A_{sf} + A_{sw} \qquad \text{Eqn. 14-22}$$

The total tension reinforcement, A_s, given by Equation 14-22 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 14-20 and β_1 and c_b are calculated from Equations 14-3 and 14-4, respectively, then compression reinforcing is required. In this 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 14-23.

$$C_w = 0.85 f'_c a_b t_s \qquad \text{Eqn. 14-23}$$

The moment resisted by the couple between the concrete web in compression and the tension steel, M_{uc}, is given by Equation 14-7.

$$M_{uc} = \phi_b C_w \left(d_{spandrel} - \frac{a_b}{2} \right) \qquad \text{Eqn. 14-24}$$

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

$$M_{us} = M_{uw} - M_{uc} \qquad \text{Eqn. 14-25}$$

Referring to Figure 14-2, the force carried by the compression steel, C_s, is given by Equation 14-26.

$$C_s = \frac{M_{us}}{d_{spandrel} - d_{r\text{-}top}} \qquad \text{Eqn. 14-26}$$

The strain in the compression steel, ε'_s, is given by Equation 14-27.

$$\varepsilon'_s = \frac{0.003\left(c - d_{r\text{-}top}\right)}{c} \qquad \text{Eqn. 14-27}$$

The stress in the compression steel, f'_s, is given by Equation 14-28.

$$f'_s = E_s \varepsilon'_s = \frac{0.003 E_s \left(c - d_{r\text{-}top}\right)}{c} \qquad \text{Eqn. 14-28}$$

In Equations 14-27 and 14-28 the term c is equal to a_b/β_1.

The required area of compression steel, A'_s; is calculated using Equation 14-29.

$$A'_s = \frac{C_s}{\phi_b f'_s} \qquad \text{Eqn. 14-29}$$

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

$$A_{sw} = \frac{M_{uc}}{\phi_b f_y \left(d_{spandrel} - \frac{a_b}{2} \right)} \qquad \text{Eqn. 14-30}$$

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

$$A_{sc} = \frac{M_{us}}{\phi_b f_y \left(d_{spandrel} - d_{r\text{-}top} \right)} \qquad \text{Eqn. 14-31}$$

The total tension reinforcement A_s is given by Equation 14-15.

$$A_s = A_{sf} + A_{sw} + A_{sc} \qquad \text{Eqn. 14-32}$$

where A_{sf}, A_{sw} and A_{sc} are determined from Equations 14-17, 14-30 and 14-31 respectively.

The total tension reinforcement, A_s, is given by Equation 14-32 and the total compression reinforcement, A'_s, is given by Equation 14-29. A_s is to be placed at the bottom of the beam and A'_s at the top of the beam.

1997 UBC Spandrel Shear Design

This chapter discusses how ETABS designs concrete wall spandrels for shear using the 1997 UBC. Note that in ETABS you can not specify shear reinforcing and then have ETABS check it. ETABS only designs the spandrel for shear and reports how much shear reinforcing is required.

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

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.

Note:

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

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

The first step above needs no further explanation. The following two sections describe in detail the algorithms associated with the last two above-mentioned steps.

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Determine the Concrete Shear Capacity

Note:

The term R_{LW} that is used as a multiplier on all $\sqrt{f'_c}$ terms in this chapter 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.

The shear force carried by the concrete, V_c, is calculated using Equation 15-1.

$$V_c = 2R_{LW}\sqrt{f'_c}\ t_s d_{spandrel} \qquad \text{Eqn. 15-1}$$

Equation 15-1 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 then ETABS 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 chapter 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 ETABS 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 15-2.

$$V_s = V_n - V_c = \frac{V_u}{\phi} - V_c \qquad \text{Eqn. 15-2}$$

If V_s as calculated in Equation 15-2 exceeds $8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}$ then a failure condition is reported per UBC Section 1911.5.6.8.

Note:

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

Given V_s, 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) is initially calculated using Equation 15-3. Note that additional requirements that are checked for both seismic and nonseismic wall spandrels are given following Equation 15-3.

$$A_v = \frac{V_n - V_c}{f_{ys} d_{spandrel}} = \frac{V_s}{f_{ys} d_{spandrel}} \qquad \text{Eqn. 15-3}$$

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

- When $\frac{L_s}{d_{spandrel}} > 5$ ETABS verifies:

$$V_s \le 8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}\,, \qquad \text{Eqn. 15-4a}$$

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

Note:

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

✓ 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:

$$A_{v\text{-min}} = \frac{50t_s}{f_{ys}} \qquad \text{Eqn. 15-4b}$$

$$A_{h\text{-min}} = 0 \qquad \text{Eqn. 15-4c}$$

Equation 15-4b 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:

$$A_{v\text{-min}} = A_{h\text{-min}} = 0 \qquad \text{Eqn. 15-4d}$$

- When $2 \le \frac{L_s}{d_{spandrel}} \le 5$ ETABS verifies:

$$V_n = \frac{V_u}{\phi} \le \frac{2}{3}\left(10 + \frac{L_s}{d_{spandrel}}\right) R_{LW}\sqrt{f'_c}\, t_s d_{spandrel} \qquad \text{Eqn. 15-4e}$$

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:

$$A_{v\text{-min}} = 0.0015t_s \qquad \text{Eqn. 15-4f}$$

$$A_{h\text{-min}} = 0.0025t_s \qquad \text{Eqn. 15-4g}$$

- When $\frac{L_s}{d_{spandrel}} < 2$ ETABS verifies:

$$V_n = \frac{V_u}{\phi} \leq 8R_{LW}\sqrt{f'_c}\,t_s d_{spandrel}, \qquad \text{Eqn. 15-4h}$$

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:

$$A_{v\text{-}min} = 0.0015t_s \qquad \text{Eqn. 15-4i}$$

$$A_{h\text{-}min} = 0.0025t_s \qquad \text{Eqn. 15-4j}$$

Equations 15-4f and 15-4i are based on Section 1911.8.9 of the 1997 UBC. Equations 15-4g and 15-4j are based on Section 1911.8.10 of the 1997 UBC.

Note that the check in Equation 15-4a is based on V_s whereas the checks in Equations 15-4e and 15-4h are based on V_n.

Seismic Spandrels Only

Note:

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

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 15-5.

$$A_{vd} = \frac{V_u}{2\,(0.85)\,f_{ys}\sin\alpha}, \qquad \text{Eqn. 15-5}$$

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.

Chapter 16

Overview of Shear Wall Output

16

This chapter provides an overview of ETABS output for shear wall design. In this context output refers to both an echo of input data and presentation of design results.

General

Note:

There are three types of shear wall design output. They are output that is displayed on the ETABS model, tabulated output displayed on screen and tabulated output that is printed.

There are three types of shear wall design output. They are output that is displayed on the ETABS model, tabulated output displayed on screen and tabulated output that is printed.

Following is a summary of the chapters included in this manual that discuss output. The chapter titles are to some degree self-explanatory. Refer to the individual chapters for additional information.

- **Chapter 4:** *Interactive Shear Wall Design and Review*. This chapter discusses the interactive design and review mode which, among other things, allows you to view tabulated output that is displayed on the screen. To enter this mode right click on a wall pier or spandrel while the design results are displayed. If design results are not currently displayed then first 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.

- **Chapter 17:** *Output Data Plotted Directly on the Model*. This chapter documents the design input and output data that can be displayed directly on the ETABS model. Use the **Design menu > Shear Wall Design > Display Design Info** command to display this data.

- **Chapter 18:** *Printed Design Input Data*. This chapter discusses the shear wall design input information that can be printed using the **File menu > Print Tables > Shear Wall Design** command. It documents each of the items in the printed Preferences data and in the printed Summary Input data.

- **Chapter 19:** *Printed Design Output Data*. This chapter discusses the shear wall design output information that can be printed using the **File menu > Print Tables > Shear Wall Design** command. It documents each of the items in the printed Output Summary data and in the printed Detailed Output data.

Chapter 17

Output Data Plotted Directly on the Model

17

Overview

Tip:

*Click the **Design menu > Shear Wall Design > Display Design Info** command to display shear wall design data directly on your ETABS model.*

This chapter describes the shear wall output that is plotted directly on the ETABS model. This output can be displayed on the screen using the **Design menu > Shear Wall Design > Display Design Info** command, and, if desired, the screen graphics can then be printed using the **File menu > Print Graphics** command. The data is organized into two main groups as follows.

- Design Input
  - ✓ Material
  - ✓ Thickness
  - ✓ Pier length/spandrel depth
  - ✓ Section Designer pier sections

- Design Output
  - ✓ Simplified pier longitudinal reinforcing
  - ✓ Simplified pier edge members
  - ✓ Section Designer pier reinforcing ratios
  - ✓ Section Designer pier D/C ratios
  - ✓ Spandrel longitudinal reinforcing
  - ✓ Shear reinforcing
  - ✓ Pier demand/capacity ratios
  - ✓ Pier boundary zones

Note that you can not simultaneously display more than one of the above listed items on the model. Each of these items is described in more detail in subsequent sections of this chapter. For some of these items it is important that you know the local axis orientation for the elements. The local axis conventions for piers and spandrels are described in the ETABS User's Manual.

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

When you choose to display the material data ETABS displays the following:

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

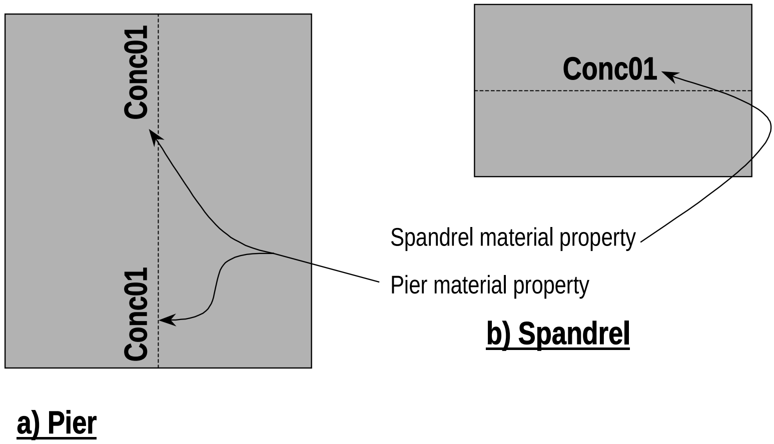


Figure 17-1: *Example of how material property labels are displayed on pier and spandrel elements*

- For Section Designer pier sections the base material property for the section is displayed. The base material is specified in the Pier Section Data dialog box that is accessed by clicking the **Design menu > Shear Wall Design > Define Pier Sections for Checking** command, and clicking either 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, is displayed.

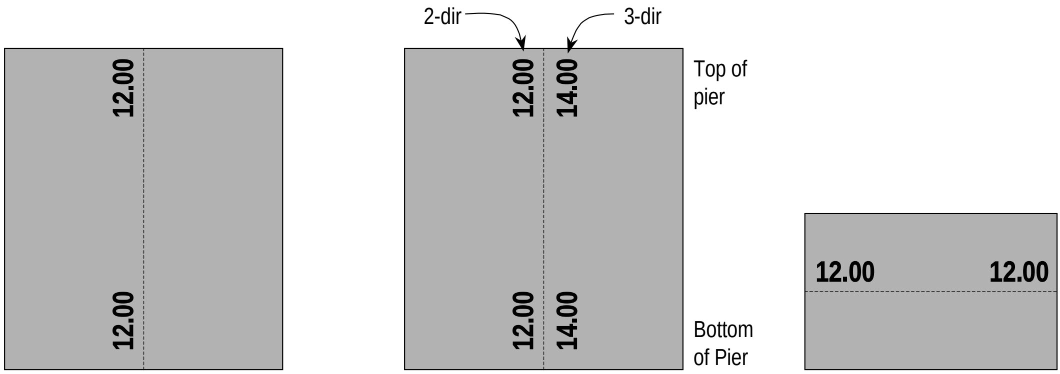
As shown in Figure 17-1, separate material properties are specified at the top and bottom of all pier sections. A single material property is displayed for spandrel sections.

Thickness

When you choose to display the thickness data ETABS displays the following:

- For simplified pier sections the pier thickness, as specified in the pier design overwrites, is displayed at the top and the bottom of the pier.

- For Section Designer pier sections the pier shear thickness, as specified in the pier design overwrites, is displayed at the top and the bottom of the pier. When the



a) Simplified Pier **b) 3D Section Designer Pier** **c) Spandrel**

Figure 17-2: *Example of how thicknesses are displayed on pier and spandrel elements. (Pier lengths and spandrels depths are displayed in a similar manner)*

pier is a three-dimensional pier then separate thicknesses are displayed for resisting forces in the local 2-axis direction and for resisting forces in the local 3-axis direction. *The thickness for the local 3-axis direction forces is always displayed to the right of the thickness for the local 2-axis direction forces.*

- For spandrels the spandrel thickness, as specified in the spandrel design overwrites, is displayed at the left end and the right end of the spandrel.

Figure 17-2 illustrates how the thicknesses are displayed on the model.

Pier Length and Spandrel Depth

When you choose to display the pier length and spandrel depth data ETABS displays the following:

- For simplified pier sections the pier length, as specified in the pier design overwrites, is displayed at the top and the bottom of the pier.

- For Section Designer pier sections the pier shear length, as specified in the pier design overwrites, is displayed at the top and the bottom of the pier. When the pier is a three-dimensional pier then separate lengths are displayed for resisting forces in the local 2-axis direction

Note:

When pier design results are displayed for both the pier local 2- and 3-axis directions, the 3-axis direction results are always displayed to the right of the 2-axis direction results.

and for resisting forces in the local 3-axis direction. *The length for the local 3-axis direction forces is always displayed to the right of the length for the local 2-axis direction forces.*

- For spandrels the spandrel *depth*, as specified in the spandrel design overwrites, is displayed at the left end and the right end of the spandrel.

The pier lengths and spandrel depths are displayed in a similar manner to that shown in Figure 17-2 for the pier and spandrel thicknesses.

Section Designer Pier Sections

When you choose to display the Section Designer pier sections ETABS displays the name of the Section Designer pier assigned to the top and bottom of the pier, if any. If the pier is a simplified pier (i.e., no Section Designer section is assigned to it) then nothing is displayed.

When ETABS displays Section Designer pier sections, the name of the section is always followed by either (C) or (D). The (C) indicates that the pier section is to be checked. The (D) indicates that the pier section is to be designed.

Design Output

Simplified Pier Longitudinal Reinforcing

When you choose to display the simplified pier longitudinal reinforcing data ETABS displays 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 Section Designer sections.

Simplified Pier Edge Members

When you choose to display the simplified pier edge member data ETABS displays either the user-defined edge member length (DB1 dimension) or the ETABS-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 Section Designer sections.

Note that if you defined an edge member length (DB1 dimension) in the pier design overwrites then ETABS uses that length in the design and it reports the length here. See the section titled "Designing a Simplified Pier Section" in Chapter 12 for more information.

Section Designer Pier Reinforcing Ratios

When you choose to display the Section Designer pier reinforcing ratios ETABS displays the maximum required reinforcing ratio at the top and bottom of all piers that are assigned Section Designer 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 area of the Section Designer section that is used in computing the 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 The required reinforcing is assumed to be provided in the same proportions as specified in the Section Designer 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.

Section Designer Pier Demand/Capacity Ratios

When you choose to display the Section Designer pier demand/capacity ratios ETABS displays the maximum demand/capacity ratio at the top and bottom of all piers that are assigned Section Designer sections and are designated to be checked. See the subsection titled "Wall Pier Demand/Capacity Ratio" in Chapter 12 for information on how ETABS 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

When you choose to display the spandrel longitudinal reinforcing data ETABS displays 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.

Shear Reinforcing

Note:

Shear reinforcing is displayed for all piers and spandrels simultaneously.

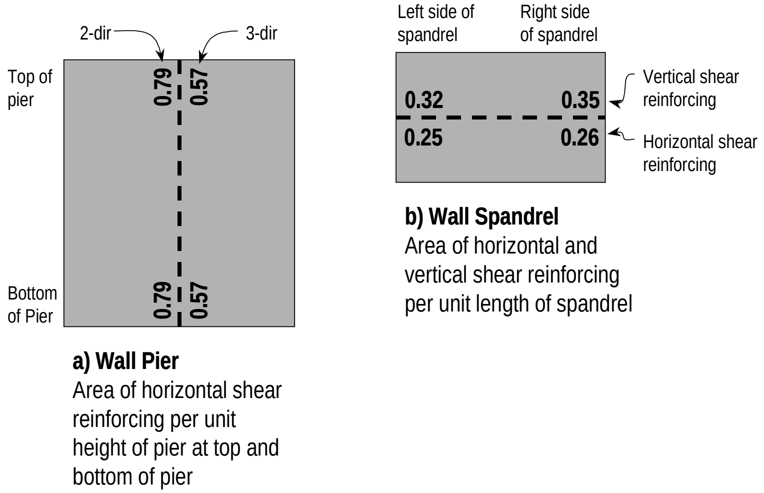
When you choose to display the shear reinforcing data ETABS displays the maximum required area of shear reinforcing for both piers and spandrels. For piers shear reinforcing areas are displayed for both the top and the bottom of the piers. When the pier is a three-dimensional pier then separate reinforcing areas are displayed for resisting forces in the local 2-axis direction and for resisting forces in the local 3-axis direction. *The shear reinforcing areas for the local 3-axis direction forces are always displayed to the right of the shear reinforcing areas for the local 2-axis direction forces.* This is illustrated in Figure 17-3 a.

For spandrel shear reinforcing refer to Figure 17-3b. The areas associated with two types of shear reinforcing are displayed. Those types of reinforcing are:

- **Distributed vertical shear reinforcement** is reported above the invisible line (shown dashed in the figure) for the left and right end of the beam.

- **Distributed horizontal shear reinforcement** is reported below the invisible line (at the ends of the beam, not in the center of the beam) for the left and right end of the beam.

Figure 17-3:
Pier and spandrel shear reinforcing



- **The total area of a single leg of diagonal shear reinforcement** is reported below the invisible line at the center 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

When you choose to display the pier boundary zone data ETABS displays 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.

For two-dimensional piers one boundary element result is displayed at the top of the pier and one at the bottom. The result at the top or bottom of the pier applies to both the left and right side of the pier.

For three-dimensional piers two boundary element results are displayed at the top of the pier and two at the bottom. These results correspond to forces in the local 2-axis direction and forces in the local 3-axis direction. *The boundary element results for the local 3-axis direction forces are always displayed to the right of the boundary element results for the local 2-axis direction forces.* Each of the displayed results applies to both the left and right side of the pier.

Printed Design Input Data

This chapter discusses the printed design input data that is available for shear wall design. It includes a description of the printout for the shear wall design preferences and for the shear wall input summary. These printouts can be obtained using the **File menu > Print Tables > Shear Wall Design** command.

Preferences

This section lists each of the column headings for the shear wall design preferences output together with a description of what is included in the column. See Chapter 8 for more information.

Flags and Factors

- **Time Hist Design:** Toggle for whether design load combinations that include a time history are designed for the envelope of the time history or designed step-by-step for the entire time history. See the section titled "Design Load Combinations that Include Time History Results" in Chapter 10 for more information.

- **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 the subsection titled "Formulation of the Interaction Surface" in Chapter 12 for more information.

Rebar Units

- **Area Units:** Units used for concentrated areas of reinforcing steel. See the section titled "Units" in Chapter 5.

- **Area/Length Units:** Units used for distributed areas of reinforcing steel. See the section titled "Units" in Chapter 5.

Simplified Pier Reinforcing Ratio Limits

- **Edge Memb PT-Max:** Maximum ratio of tension reinforcing allowed in edge members of simplified piers, PT_{max}. See the subsection titled "Design Condition 1" in Chapter 12.

- **Edge Memb PC-Max:** Maximum ratio of compression reinforcing allowed in edge members of simplified piers, PC_{max}. See the subsection titled "Design Condition 1" in Chapter 12.

Interaction Surface Data

- **Number Curves:** Number of equally spaced interaction curves used to create a full 360 degree interaction surface. See the section titled "Interaction Surface" in Chapter 12 for more information.

- **Number Points:** Number of points used for defining a single curve in a wall pier interaction surface. See the section titled "Interaction Surface" in Chapter 12 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 the section titled "Designing a Section Designer Pier Section" in Chapter 12.

- **Sect Des IP-Min:** 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 Chapter 12.

Input Summary

This section lists each of the column headings for the shear wall input summary data together with a description of what is included in the column.

Pier Location Data

Note:

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

- **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, designating 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 for whether ETABS will design the pier. It is either Yes or No. This item corresponds to the Design this Pier item in the pier design overwrites.

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- **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 ETABS then it is reported here as "Prog Calc."

- **Quake Factor:** A multiplier applied to horizontal earthquake loads. This item corresponds to the Horizontal EQ Factor item in the pier design overwrites. See the subsection titled "Horizontal EQ Factor" in Chapter 9 for more information.

- **Design Type:** This item is either Seismic or Nonseis. Additional design checks are done for seismic elements compared to nonseismic elements. Also in some cases the strength reduction factors are different.

- **Props From:** This item is either Simple or Sect Des. It indicates where the properties for the pier section come from. Simple means that the pier is a simplified section and Sect Des means that it is assigned Section Designer sections. This item corresponds to the Properties From item in the pier design overwrites.

- **Pier is 3D:** This item is either Yes or No indicating whether the pier is considered two-dimensional or three-dimensional for design.

- **Edge Memb PT-Max:** Maximum ratio of tension reinforcing allowed in edge members of simplified piers, PT_{max}. See the subsection titled "Design Condition 1" in Chapter 12. If the pier considered is not a simplified pier (i.e., it is a Section Designer pier) then this item is N/A.

- **Edge Memb PC-Max:** Maximum ratio of compression reinforcing allowed in edge members of simplified piers, PC_{max}. See the subsection titled "Design Condition 1" in Chapter 12. If the pier considered is not a simplified pier (i.e., it is a Section Designer pier) then this item is N/A.

Pier Geometry Data (Simplified Section)

- **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. If this item is calculated by ETABS then it is reported here as "Prog Calc."

- **Station Location:** This is either Top or Bottom, designating 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 ETABS then it is reported here as "Prog Calc."

- **Pier Length:** The design length of the pier. If the value of this item is calculated by ETABS then 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 6-1 in Chapter 6.

- **DB2 Left:** The user-defined width of the edge member at the left end of the pier. See Figure 6-1 in Chapter 6.

- **DB1 Right:** The user-defined length of the edge member at the right end of the pier. See Figure 6-1 in Chapter 6.

- **DB2 Right:** The user-defined width of the edge member at the right end of the pier. See Figure 6-1 in Chapter 6.

Pier Geometry Data (Section Designer Section)

- **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 Section Designer pier section assigned to the bottom of the pier.

- **Top Pier Section:** The name of the Section Designer 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 discussed in the Section Designer Manual.

- **Top Pier Material:** The base material property associated with the section at the top of the pier. The base material is discussed in the Section Designer Manual.

Note:

The Shear Length and Shear Thick items apply to both the top and the bottom of the pier.

- **V2 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction. This item applies to both the top and bottom of the pier and it corresponds to the V2 Length item in the pier design overwrites. If the value of this item is calculated by ETABS then it is reported here as "Prog Calc."

- **V2 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction. This item applies to both the top and bottom of the pier and it corresponds to the V2 Thickness item in the pier design overwrites. If the value of this item is calculated by ETABS then it is reported here as "Prog Calc."

- **V3 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction. This item applies to both the top and bottom of the pier and it corresponds to the V3 Length item in the pier design overwrites. If the pier is two-dimensional then this item is reported as N/A. If the value of this item is calculated by ETABS then it is reported here as "Prog Calc."

- **V3 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction. This item applies to both the top and bottom of the pier and it corresponds to the V3 Thickness item in the pier design overwrites. If the pier is two-dimensional then this item is reported as N/A. If the value of this item is calculated by ETABS then it is reported here as "Prog Calc."

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.

- **Station Location:** This is either Left or Right designating 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 for whether ETABS will 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 ETABS then it is reported here as "Prog Calc."
- **Design Type:** This item is either Seismic or Nonseis. Additional design checks are done for seismic elements compared to nonseismic 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 ETABS then it is reported here as "Prog Calc."
- **Consider Vc:** A toggle switch for whether to consider 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, designating 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 ETABS then it is reported here as "Prog Calc."

- **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 ETABS then 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 then this item is zero.

- **Flange Depth:** Depth of the flange for a T-beam. If the spandrel is not a T-beam then 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 ETABS then 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 ETABS then it is reported here as "Prog Calc."

Printed Design Output Data

This chapter discusses the printed design output data that is available for shear wall design. It includes a description of the printout for the shear wall output summary and for the shear wall detailed output. These printouts can be obtained using the **File menu > Print Tables > Shear Wall Design** command.

Output Summary

This section lists each of the column headings for the shear wall output summary together with a description of what is included in the column.

Simplified Pier Section Design

- **Story Label:** Label of the story level associated with the pier.

- **Pier Label:** Label assigned to the pier.

- **Station Location:** This is either Top or Bottom, designating 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 ETABS-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 ETABS-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 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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35.

Section Designer Pier Section Design

- **Story Label:** Label of the story level associated with the pier.

- **Pier Label:** Label assigned to the pier.

- **Station Location:** This is either Top or Bottom, designating the top or the bottom of the pier.

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.

- **Pier Section:** The name of the Section Designer section assigned to the pier at the considered station location (top or bottom of pier).

- **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, suppose the Current Ratio (see next item) is 0.0200 and the Required Ratio is 0.0592. Then 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.

- **Av 2-Dir:** The maximum area per unit length (height) of horizontal reinforcing steel required to resist shear in the pier local 2-axis direction.

Note:

See Chapter 11 for discussion of the ETABS boundary zone check.

- **B-Zone Length-2:** 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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35. This item applies to forces acting in the pier local 2-axis direction.

- **Av 3-Dir:** The maximum area per unit length (height) of horizontal reinforcing steel required to resist shear in the pier local 3-axis direction. This item only applies to three-dimensional piers.

- **B-Zone Length-3:** 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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35. This item applies to forces acting in the pier local 3-axis direction and it only applies to three-dimensional piers.

Section Designer Pier Section Check

- **Story Label:** Label of the story level associated with the pier.

- **Pier Label:** Label assigned to the pier.

- **Station Location:** This is either Top or Bottom, designating 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.

- **Av 2-Dir:** The maximum area per unit length (height) of horizontal reinforcing steel required to resist shear in the pier local 2-axis direction.

- **B-Zone Length-2:** 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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35. This item applies to forces acting in the pier local 2-axis direction.

- **Av 3-Dir:** The maximum area per unit length (height) of horizontal reinforcing steel required to resist shear in the pier local 3-axis direction. This item only applies to three-dimensional piers; it is reported as N/A for two-dimensional piers.

- **B-Zone Length-3:** 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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35. This item applies to forces acting in the pier local 3-axis direction and it only applies to three-dimensional piers and it is reported as N/A for two-dimensional piers.

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 designating 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 the section titled "Determine the Concrete Shear Capacity" in Chapter 15 for more information.

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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.

Detailed Output Data

This section lists each of the column headings for the pier and spandrel detailed output data together with a description of what is included in the column. The four types of detailed output available are:

- Simplified pier section design.
- Section Designer pier section *design*.
- Section Designer pier section *check*.
- Spandrel design.

Each of these types of output is described in separate subsections below.

Simplified Pier Section Design

- **Pier Label:** Label assigned to the pier.
- **Story Label:** Label of the story level associated with the pier.

Location Data

- **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, designating the top or the bottom of the pier.

- **Xc Ordinate:** The global X-coordinate of the centroid of the pier station (top or bottom) considered.

- **Yc Ordinate:** The global Y-coordinate of the centroid of the pier station (top or bottom) considered.

- **Zc Ordinate:** The global Z-coordinate of the centroid of the pier station (top or bottom) considered.

Flags and Factors

- **Design Active:** Toggle for whether ETABS will 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.

- **EQ Factor:** A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See the subsection titled "EQ Factor" in Chapter 9 for more information.

- **Design Type:** This item is either Seismic or Nonseismic. Additional design checks are done for seismic elements compared to nonseismic elements. Also in some cases the strength reduction factors are different.

- **Edge Memb PT-Max:** Maximum ratio of tension reinforcing allowed in edge members of simplified piers, PT_{max}. See the subsection titled "Design Condition 1" in Chapter 12. If the pier considered is not a simplified pier (i.e., it is a Section Designer pier) then this item is N/A.

- **Edge Memb PC-Max:** Maximum ratio of compression reinforcing allowed in edge members of simplified piers, PC_{max}. See the subsection titled "Design Condition 1" in Chapter 12. If the pier considered is not a simplified pier (i.e., it is a Section Designer pier) then this item is N/A.

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Material and Geometry Data

- **Pier Material:** The material property associated with the pier.

- **Station Location:** This is either Top or Bottom, designating the top or the bottom of the pier.

- **Pier Thick:** The design thickness of the pier.

- **Pier Length:** The design length of the pier.

- **DB1 Left:** The user-defined length of the edge member at the left end of the pier. See Figure 6-1 in Chapter 6.

- **DB2 Left:** The user-defined width of the edge member at the left end of the pier. See Figure 6-1 in Chapter 6.

- **DB1 Right:** The user-defined length of the edge member at the right end of the pier. See Figure 6-1 in Chapter 6.

- **DB2 Right:** The user-defined width of the edge member at the right end of the pier. See Figure 6-1 in Chapter 6.

Flexural Design Data

The flexural design data is reported separately for tension design and for compression design. You should check the steel area required for both tension and compression design and use the maximum for your pier.

Tension Design

- **Station Location:** This is Left Top, Right Top, Left Bottom or Right Bottom, designating the location of the reported reinforcing steel.

- **Edge Length:** Length of the ETABS-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 you have specified specific rebar area units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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.

Compression Design

- **Station Location:** This is Left Top, Right Top, Left Bottom or Right Bottom, designating the location of the reported reinforcing steel.

- **Edge Length:** Length of the ETABS-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 you have specified specific rebar area units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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

- **Station Location:** This is either Top 2-dir or Bot 2-dir designating the location (top or bottom) of the reported shear reinforcing steel and the direction of force (pier local 2-axis) for which the steel is provided.

- **Rebar:** Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 either Top 2-dir or Bot 2-dir designating 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.

Note:

See Chapter 11 for more information on the boundary element check.

- **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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35.

When this item is Not Needed or Not Checked ETABS 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 Pu/Po value. Otherwise ETABS 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 then ETABS does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Additional Overwrite Information

Some of the input data items reported on the detailed output sheet can either be calculated by the program or user input. This area of the output lists those input data items and indicates that they are either Prog Calc (program calculated) or User Input. The actual values used for these items are reported elsewhere on the detailed output sheet.

- **RLLF:** A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.
- **Pier Material:** The material property associated with the pier.
- **Station Location:** This is either Top or Bottom, designating the top or the bottom of the pier.

- **Pier Thick:** The design thickness of the pier.

- **Pier Length:** The design length of the pier.

Section Designer Pier Section Design

- **Pier Label:** Label assigned to the pier.

- **Story Label:** Label of the story level associated with the pier.

Location Data

- **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, designating the top or the bottom of the pier.

- **Xc Ordinate:** The global X-coordinate of the centroid of the pier station (top or bottom) considered.

- **Yc Ordinate:** The global Y-coordinate of the centroid of the pier station (top or bottom) considered.

- **Zc Ordinate:** The global Z-coordinate of the centroid of the pier station (top or bottom) considered.

Flags and Factors

- **Design Active:** Toggle for whether ETABS will 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.

- **EQ Factor:** A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See the subsection titled "EQ Factor" in Chapter 9 for more information.

- **Design Type:** This item is either Seismic or Nonseismic. Additional design checks are done for seismic elements compared to nonseismic elements. Also in some cases the strength reduction factors are different.

- **Pier is 3D:** This item is either Yes or No indicating whether the pier is considered two-dimensional or three-dimensional for design.

Material and Geometry Data

- **Bot Pier Section:** The name of the Section Designer section assigned to the bottom of the pier.

- **Top Pier Section:** The name of the Section Designer section assigned to the top of the pier.

- **Bot Pier Material:** The base material property associated with the pier section assigned to the bottom of the pier. The base material is discussed in the Section Designer Manual.

- **Top Pier Material:** The base material property associated with the pier section assigned to the top of the pier. The base material is discussed in the Section Designer Manual.

- **V2 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction.

- **V2 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction.

- **V3 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction. This item is reported as N/A if the pier is two-dimensional.

- **V3 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction. This item is reported as N/A if the pier is two-dimensional.

Flexural Design Data

- **Station Location:** This is either Top or Bottom designating 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. 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, suppose the Current Reinf Ratio (see next item) is 0.0200 and the Required Reinf Ratio is 0.0592. Then 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.

Note:

The area of the Section Designer 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.

- **Current Reinf 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.

- **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.

Shear Design Data

- **Station Location:** This is Top 2-dir, Top 3-dir, Bot 2-dir or Bot 3-dir, designating the location (top or bottom) of the reported shear reinforcing steel and the direction of force (pier local 2-axis or pier local 3-axis) for which the steel is provided. The Top 3-dir and Bot 3-dir items only appear if the Design Pier is 3D item in the pier overwrites is set to Yes for the pier considered.
- **Rebar:** Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 2-dir, Top 3-dir, Bot 2-dir or Bot 3-dir, designating the location (top or bottom) of the boundary element check and the direction of force (pier local 2-axis or pier local 3-axis) for which the boundary elements are checked. The Top 3-dir and Bot 3-dir items only appear if the Design Pier is 3D item in the pier overwrites is set to Yes for the pier considered.

Note:

See Chapter 11 for more information on the boundary element check.

- **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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35.

  When this item is Not Needed or Not Checked ETABS 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 Pu/Po value. Otherwise ETABS 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 then ETABS does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Additional Overwrite Information

Some of the input data items reported on the detailed output sheet can either be calculated by the program or user input. This area of the output lists those input data items and indicates that they are either Prog Calc (program calculated) or User Input. The actual values used for these items are reported elsewhere on the detailed output sheet.

- **RLLF:** A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.

- **V2 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction.

- **V2 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction.

- **V3 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction.

- **V3 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction.

Section Designer Pier Section Check

- **Pier Label:** Label assigned to the pier.

- **Story Label:** Label of the story level associated with the pier.

Location Data

- **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, designating the top or the bottom of the pier.

- **Xc Ordinate:** The global X-coordinate of the centroid of the pier station (top or bottom) considered.

- **Yc Ordinate:** The global Y-coordinate of the centroid of the pier station (top or bottom) considered.

- **Zc Ordinate:** The global Z-coordinate of the centroid of the pier station (top or bottom) considered.

Flags and Factors

- **Design Active:** Toggle for whether ETABS will 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.

- **EQ Factor:** A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the pier design overwrites. See the subsection titled "EQ Factor" in Chapter 9 for more information.

- **Design Type:** This item is either Seismic or Nonseismic. Additional design checks are done for seismic elements compared to nonseismic elements. Also in some cases the strength reduction factors are different.

- **Pier is 3D:** This item is either Yes or No indicating whether the pier is considered two-dimensional or three-dimensional for design.

Material and Geometry Data

- **Bot Pier Section:** The name of the Section Designer section assigned to the bottom of the pier.

- **Top Pier Section:** The name of the Section Designer section assigned to the top of the pier.

- **Bot Pier Material:** The base material property associated with the pier section assigned to the bottom of the pier. The base material is discussed in the Section Designer Manual.

- **Top Pier Material:** The base material property associated with the pier section assigned to the top of the pier. The base material is discussed in the Section Designer Manual.

- **V2 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction.

- **V2 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction.

- **V3 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction. This item is reported as N/A if the pier is two-dimensional.

- **V3 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction. This item is reported as N/A if the pier is two-dimensional.

Flexural Design Data

- **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.

- **Flexural Combo:** The design load combination that yields the largest flexural Demand/Capacity 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.

Shear Design Data

- **Station Location:** This is Top 2-dir, Top 3-dir, Bot 2-dir or Bot 3-dir, designating the location (top or bottom) of the reported shear reinforcing steel and the direction of force (pier local 2-axis or pier local 3-axis) for which the steel is provided. The Top 3-dir and Bot 3-dir items only appear if the Design Pier is 3D item in the pier overwrites is set to Yes for the pier considered.

- **Rebar:** Maximum area per unit length (height) of horizontal reinforcing steel required to resist shear. If you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 2-dir, Top 3-dir, Bot 2-dir or Bot 3-dir, designating the location (top or bottom) of the boundary element check and the direction of force (pier local 2-axis or pier local 3-axis) for which the boundary elements are checked. The Top 3-dir and Bot

3-dir items only appear if the Design Pier is 3D item in the pier overwrites is set to Yes for the pier considered.

- **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 done by ETABS because the ratio P_u/P_o is greater than or equal to 0.35.

  When this item is Not Needed or Not Checked ETABS 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 Pu/Po value. Otherwise ETABS fills in the data from the design load combination that requires the longest boundary zone length.

Note:

See Chapter 11 for more information on the boundary element check.

- **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 then ETABS does not check the boundary zone requirement. See Section 1921.6.6.3 in the 1997 UBC.

Additional Overwrite Information

Some of the input data items reported on the detailed output sheet can either be calculated by the program or user input. This area of the output lists those input data items and indicates that they are either Prog Calc (program calculated) or User Input. The actual values used for these items are reported elsewhere on the detailed output sheet.

- **RLLF:** A reducible live load acting on a pier is multiplied by this factor to obtain the reduced live load.

- **V2 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction.

- **V2 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 2-axis direction.

- **V3 Length:** Length of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction.

- **V3 Thickness:** Thickness of the effective rectangular pier used for shear and boundary element design for shear forces in the pier local 3-axis direction.

Spandrel Design

- **Spandrel Label:** Label assigned to the spandrel.

- **Story Label:** Label of the story level associated with the spandrel.

Location Data

- **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.

- **Station Location:** This is either Left or Right, designating the left end or the right end of the spandrel.

- **Xc Ordinate:** The global X-coordinate of the centroid of the spandrel station (left or right) considered.

- **Yc Ordinate:** The global Y-coordinate of the centroid of the spandrel station (left or right) considered.

- **Zc Ordinate:** The global Z-coordinate of the centroid of the spandrel station (left or right) considered.

Flags and Factors

- **Design Active:** Toggle for whether ETABS will 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.

- **EQ Factor:** A multiplier applied to earthquake loads. This item corresponds to the EQ Factor item in the spandrel design overwrites. See the subsection titled "EQ Factor" in Chapter 9 for more information.

- **Design Type:** This item is either Seismic or Nonseismic. Additional design checks are done for seismic elements compared to nonseismic elements. Also in some cases the strength reduction factors are different.

- **Consider Vc:** A toggle switch for whether to consider V_c (the concrete shear capacity) when computing the shear capacity of the spandrel. This item is either yes or no.

Material and Geometry Data

- **Spandrel Material:** The material property associated with the spandrel.

- **Spandrel Length:** The length of the spandrel measured from the left end of the spandrel to the right end.

- **Station Location:** This is either Left or Right designating the left end or the right end of the spandrel.

- **Spandrel Height:** Full height (depth) of the spandrel.

- **Spandrel Thick:** Thickness (width) of the spandrel. For T-beams this is the width of the beam web.

- **Flange Width:** Full width of the flange for a T-beam. If the spandrel is not a T-beam then this item is zero.

- **Flange Depth:** Depth of the flange for a T-beam. If the spandrel is not a T-beam then this item is zero.

- **Cover Top:** Distance from the top of the beam to the centroid of the top longitudinal reinforcing.

- **Cover Bot:** Distance from the bottom of the beam to the centroid of the bottom longitudinal reinforcing.

Flexural Design Data - Top Steel

- **Station Location:** This is either Left or Right designating that the output reported is for the left or right end of the spandrel.

- **Top Steel:** The area of top steel required for the Top Steel Combo. If you have specified specific rebar area units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 4-1.

$$\text{Top Steel Ratio} = \frac{A_{s\ top}}{t_s\left(h_s - d_{r-top}\right)} \qquad \text{Eqn. 4-1}$$

- **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.

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Flexural Design Data - Bottom Steel

- **Station Location:** This is either Left or Right designating that the output reported is for the left or right end of the spandrel.

- **Bot Steel:** The area of bottom steel required for the Bot Steel Combo. If you have specified specific rebar area units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 4-2.

$$\text{Bot Steel Ratio} = \frac{A_{s\,bot}}{t_s\left(h_s - d_{r-bot}\right)} \qquad \text{Eqn. 4-2}$$

- **Bot Steel Combo:** The name of the design load combination that requires the most bottom steel in the spandrel.

- **Mu:** The factored design moment associated with the Bot Steel Combo.

Shear Design Data

- **Station Location:** This is either Left or Right, designating 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 you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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 you have specified specific rebar area/length units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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.

Additional Shear Design Data for Seismic Spandrels

- **Station Location:** This is either Left or Right, designating that the output reported is for the left or right end of the spandrel.

Note:

This additional shear output data is only provided if the Design Type item in the output titled Basic Overwrite Data is set to Yes for the spandrel.

- **Adiag:** The area of diagonal shear steel required for the Shear Combo. If you have specified specific rebar area units in the shear wall preferences then those units are displayed in the column heading. If no specific units are displayed in the column heading then 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.

Additional Overwrite Information

Some of the input data items reported on the detailed output sheet can either be calculated by the program or user input. This area of the output lists those input data items and indicates that they are either Prog Calc (program calculated) or User Input. The actual values used for these items are reported elsewhere on the detailed output sheet.

- **RLLF:** A reducible live load acting on a spandrel is multiplied by this factor to obtain the reduced live load.
- **Spandrel Material:** The material property associated with the spandrel.
- **Spandrel Length:** The length of the spandrel measured from the left end of the spandrel to the right end.
- **Station Location:** This is either Left or Right designating the left end or the right end of the spandrel.
- **Spandrel Height:** Full height (depth) of the spandrel.
- **Spandrel Thick:** Thickness (width) of the spandrel. For T-beams this is the width of the beam web.
- **Cover Top:** Distance from the top of the beam to the centroid of the top longitudinal reinforcing.
- **Cover Bot:** Distance from the bottom of the beam to the centroid of the bottom longitudinal reinforcing.

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