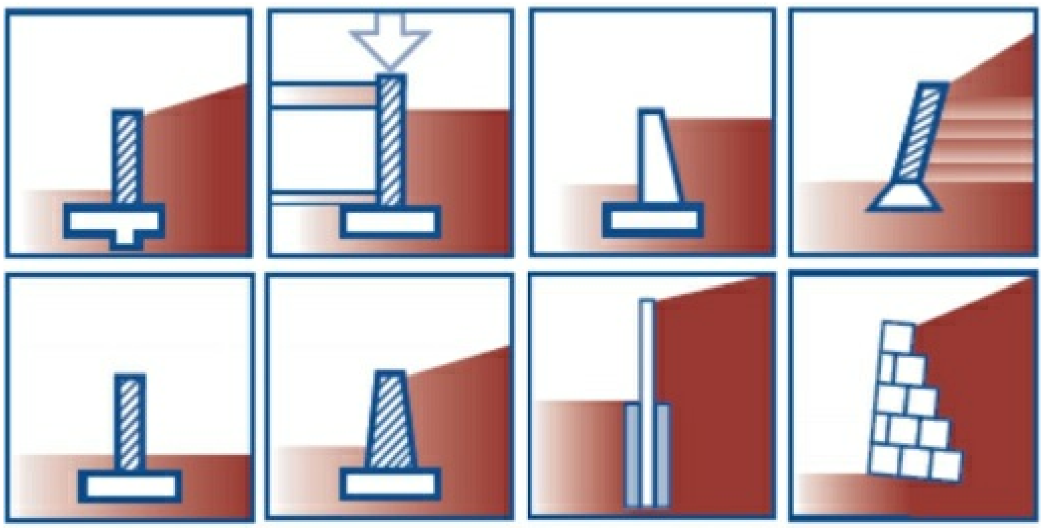
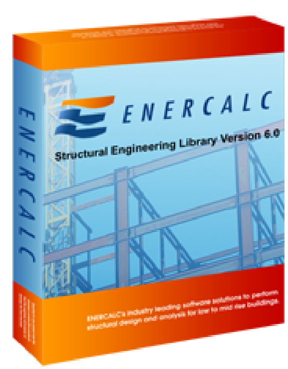
RetainPro 10



Retaining Wall Design



ENERCALC, INC

RetainPro 10

Cantilevered Retaining Walls
Restrained Retaining Walls
Gravity Retaining Walls
Gabion Walls
Segmental Block Retaining Walls
Soldier Pile Walls

A product of

ENERCALC, INC.

RetainPro

Publisher

ENERCALC, INC.

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RetainPro 10 User's Reference
December 2011
Newport Beach, CA, USA

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Part I

1 Caution!!

CAUTION!!

RetainPro is intended to be a design aid for persons already having the technical ability to design retaining walls in accordance with accepted structural engineering principles and applicable building codes. Design criteria used, input values, and all results from this program should be verified.

The final design and/or analysis shall be the responsibility of the person(s) using the program and its results.

Program developers, RetainPro Software div. ENERCALC, Inc., their owners, and employees, are not responsible for anything resulting from the use of this program or its calculated values or drawings.

Your acceptance of these conditions is a condition for its use. If you do not agree to accept these conditions and responsibility, you should return the program disk and accompanying documentation, retaining no copies and with a statement that it has not been installed on your computer, within 60 days of receipt and receive a refund of purchase price excluding shipping charges.

Part II

2 Just a Minute! Please Read this First

Just a Minute! Please Read This First

We know you want to jump right in, but even if you are upgrading from a previous version, please read through this User's Manual first. True, you may not need to, especially since the program is quite intuitive and helpful prompts are everywhere, but a read-through will be an excellent investment of 30 minutes of your time.

We assure you that you will save time by doing this - and perhaps an unnecessary phone call to us. Nearly all of the entries are explained, and in particular, you should read the *Methodology / Analysis & Design Assumptions* section of the respective wall modules that you plan to use.

And again, a reminder to check our Website often at www.retainpro.com.

We occasionally release updates with changes and/or enhancements. You will be notified of these by our auto-update feature where you will be notified automatically if any are available.

This manual is available in pdf format under the Help & Tutorials Menu.

If you change your email address you MUST notify us at www.retainpro.com/support, or you will not receive our newsletters or other announcements.

Part III

3 Quick Start Tutorial

Quick Start Tutorial

This is just a brief summary to get you started and instructs you on only a few of the most-used wall types. It is very important that you also read the User's Manual which you can download in .pdf format under the Help & Tutorials tab on the Tool Bar.

- First Time Familiarization
- Starting Your First Wall Design
- Basic Data Input Tips
- Opening an Existing File
- Using Wall Wizard and View Tab
- Designing a Cantilevered Wall
- Designing a Tapered Stem Wall
- Designing a Gravity Wall

3.1 First Time Familiarization

First Time Familiarization

1. For a first time familiarization tour, from the **Project Assistant** (the opening screen) select **Open a Project File**.

2. Select **Examples.RPX** and click **Open.**

3. Select **EX-1** (or any other) and click **Edit**.

4. **DON'T CHANGE ANY VALUES – JUST EXPLORE FOR NOW.**

5. Look over the **View** tab screen to see what values you can enter there. Note that IF you enter data, this drawing will not change scale, but if you were to click on the **Construction** tab at upper right, you WOULD see changes reflected.

6. **Click on each of the tabs, and their sub-tabs,** from left to right. You will be entering data on these tabs as you do your design. The far right tab, **Calc Info**, is where you enter specific information about the wall you're designing which will appear on your printout.

7. Click on the four tabs on the right window **(Results, Construction, Wall Loading, and Diagram)**, just to see what they show.

8. Click on **Settings > User Information** in the main menu. This would be a good time to enter your registration information. You can also use the **Printing & Title Block** tab for information you want to appear put on your printout and to import a logo for your printouts.

9. Close the Global Settings window and click on the **Stem** tab. This is an important tab for designing the stem.

10. Click on the **Help** button at upper right, then click on the various selections to see what's there.

11. Click **Cancel > No** to return you to the **Project Files** directory, then click the **Close** button on the left end of the toolbar. Finally, click **File > Exit** to close RetainPro.

3.2 Starting Your First Wall Design

Starting Your First Wall Design

1. For your first wall design, launch RetainPro and click **Create a Project File** in the Project Assistant.

2. On the Create New RetainPro Project File dialog give it a name, such as Practice Walls, or if you have a project ready to start, use the name of the project. Think of this as a file where you will keep all the walls you design for this project. After naming the file, click **Save.**

3. You'll now see a blank screen (it will fill up as you design walls for this project).

4. Click **Insert** and you will have a screen with choices for the types of walls the program can design.

5. When you select a wall type, you will first get a screen to enter the information about the wall (for example: "12 ft East Property Line Wall"). What you enter will appear on your printouts.

6. When you are done experimenting with this wall calculation, click the Save & Exit button in the upper right corner of the screen.

7. To continue, refer to the tutorial topic for the specific type of wall you have selected.

3.3 Basic Data Input Tips

Basic Data Input Tips

1. As you navigate the program, if a button is dimmed, it just means it's not applicable or available for that window.

2. To enter data into a field, use the spin buttons, or highlight the field and type in a new value and then click in another input filed to "register" the data you just entered.

3. You can use the Tab key to advance to another (usually the next) entry. DON'T USE THE "ENTER" KEY!

4. If an entry doesn't "stick" (stay in place), just highlight the cell, **Delete** it, and re-enter.

5. Occasionally you will encounter checkboxes, where you check or uncheck depending upon your intent.

3.4 Opening an Existing File

Opening an Existing File

1. From the main menu click **File > Open Project**.
2. Highlight the file you want and click **Open.**
3. Highlight the wall you want to work with and click **Edit** to display it.

3.5 Using Wall Wizard and View Tab

Using Wall Wizard and View Tab

If you're new to RetainPro, this will be a big help. By answering questions about your design you will be led step-by-step through the data input process. But you will then need to complete your design as instructed under the various wall types in this tutorial.

NOTE: Wall Wizard is available for cantilevered, restrained, tapered, and gravity walls only.

The **View** tab is another helpful option if you're just becoming acquainted with the program. It allows the user to input values onto the screen which are then inserted into the appropriate input fields, allowing the user to proceed with finalizing the design.

3.6 Designing a Cantilevered Wall

Designing a Cantilevered Wall

1. Assuming you're not using Wall Wizard, click the **Insert** button.

2. In the Choose Add Method dialog click **Cantilevered Wall**.

3. The screen will automatically display the **Calc Info** tab. Here, you must select the desired Building Code and Unit system, and you may enter data in the Wall Specific Information fields if desired (Job Title, Job Number, etc.) The Wall Specific Information is used to populate the title block when printing.

4. If you're just getting acquainted, you may want to use the **View** tab to enter initial geometry, and then go on to the other tabs, where you will find your initial entries will have already been placed in the appropriate fields.

5. Alternatively, you can skip **View** tab and just go directly to the other tabs to enter all your data.

6. The **General** tab collects information about the wall geometry, the soil, and some design decisions.

7. The **Loads** tab collects information about the vertical and lateral loads acting on the wall. (Be sure to use both the **Loads** and the **Seismic** sub-tabs when appropriate.)

8. The **Stem** tab is used to thoroughly define the stem and its reinforcing. Before using this tab please carefully read the procedure in the User's Manual. You design the stem starting at the bottom, where the moments and shears are highest. By default, the starting "Design Height" is zero. Note that the "Design Height" is the height above the footing where you want to check the design. At each Design Height you can change material, thickness, or reinforcing, to economize your design as moments and shears decrease. There should generally be at least two feet between any such changes. Usually only two Design Heights will be required: At the top of the footing, and at the top of the dowels extending up from the footing. If the wall is high, say over eight feet, you may want to check it higher, say at six feet. Rarely would you need to specify more than three heights to check.

9. The **Footing** tab is used to define the footing (including the key if one is used), to specify the associated reinforcing, and to make some design decisions regarding how the program will handle the calculations for sliding checks.

10. At any time during the process of entering the wall design data you can view the right screen tabs to see a **Results** summary, and a tabulation of **Resisting and Overturning Moments**, and the **Tilt** calculation.

11. Once sufficient geometry and loading data have been entered, the **Construction** tab will display a schematic drawing, and the **Wall Loading** tab will display color-coded loading diagrams. The **Diagrams** tab displays diagrams of the applied and resisting shears and moments in the stem.

12. When you’re done, click **Save** to save your Project File with the latest design.

3.7 Designing a Tapered Stem Wall

Designing a Tapered Stem Wall

1. Assuming you're not using Wall Wizard, click the **Insert** button.

2. In the Choose Add Method dialog click **Tapered Wall**.

3. The screen will automatically display the **Calc Info** tab. Here, you must select the desired Building Code and Unit system, and you may enter data in the Wall Specific Information fields if desired (Job Title, Job Number, etc.) The Wall Specific Information is used to populate the title block when printing.

4. The **General** tab collects information about the wall geometry, the soil, and some design decisions.

5. The **Loads** tab collects information about the vertical and lateral loads acting on the wall. (Be sure to use both the **Loads** and the **Seismic** sub-tabs when appropriate.)

6. The **Stem** tab collects geometry and reinforcing information pertinent to the stem. Note that for a Tapered Stem Wall, only the back face can be tapered (battered), and it is only available for concrete stems (Masonry can't be tapered). Before using this tab please carefully read this procedure in the User's Manual. First enter the thickness of the stem at the top and at the base. You then design the stem starting at the bottom, where the moments and shears are highest. By default, the starting "Design Height" is zero. Note that the "Design Height" is the height above the footing where you want to check the design. You can check the wall at two heights above the base. At each height you select, the program will automatically compute the thickness for stress determinations. For each Design Height select the reinforcing that gives you an efficient stress ratio (close to but not exceeding 1.0).

7. The **Footing** tab is used to define the footing (including the key if one is used), to specify the associated reinforcing, and to make some design decisions regarding how the program will handle the calculations for sliding checks.

8. At any time during the process of entering the wall design data you can view the right screen tabs to see a **Results** summary, and a tabulation of **Resisting and Overturning Moments**, and **Tilt** calculation.

9. Once sufficient geometry and loading data have been entered, the **Construction** tab will display a schematic drawing, and the **Wall Loading** tab will display color-coded loading diagrams. The **Diagrams** tab displays diagrams of the applied and resisting shears and moments in the stem.

10. When you're done, click **Save** to save your Project File with the latest design.

3.8 Designing a Gravity Wall

Designing a Gravity Wall

1. Assuming you're not using Wall Wizard, click the **Insert** button.

2. In the Choose Add Method dialog click **Gravity Wall**.

3. The screen will automatically display the **Calc Info** tab. Here, you must select the desired Building Code and Unit system, and you may enter data in the Wall Specific Information fields if desired (Job Title, Job Number, etc.) The Wall Specific Information is used to populate the title block when printing.

4. The **General** tab collects information about the wall geometry and the soil.

5. The **Loads** tab collects information about the vertical and lateral loads acting on the wall. (Be sure to use both the **Loads** and the **Seismic** sub-tabs when appropriate.)

6. The **Stem** tab collects geometry and reinforcing information pertinent to the stem. Enter wall weight (usually masonry rubble, about 145 pcf), then the dimensions defining the front batter distance, the top thickness and the back batter distance. You then design the stem starting at the bottom, where the moments and shears are highest. By default, the starting "Design Height" is zero. Note that the "Design Height" is the height above the footing where you want to check the design. You can check the wall at two heights above the base. At each height you select, the program will automatically compute the thickness for stress determinations, and compute the section modulus at that height.

7. The **Footing** tab is used to define the footing (including the key if one is used), to specify the associated reinforcing, and to make some design decisions regarding how the program will handle the calculations for sliding checks.

8. At any time during the process of entering the wall design data you can view the right screen tabs to see a **Results** summary, and a tabulation of **Resisting and Overturning Moments**, and **Tilt** calculation.

9. Once sufficient geometry and loading data have been entered, the **Construction** tab will display a schematic drawing, and the **Wall Loading** tab will display color-coded loading diagrams. The **Diagrams** tab displays diagrams of the applied and resisting shears and moments in the stem.

10. When you're done, click **Save** to save your Project File with the latest design.

Part IV

4 All Walls

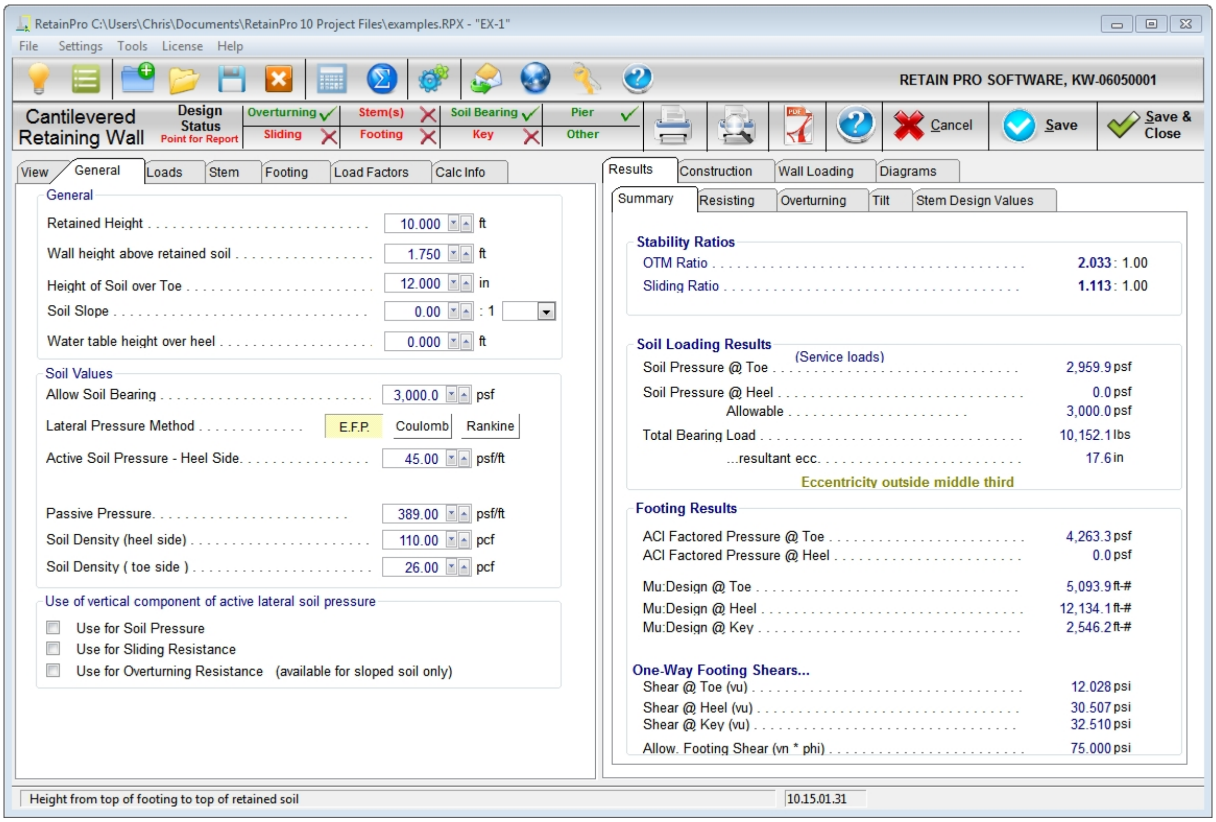
All Walls

The following topics generally apply to all wall types except where noted specifically.

4.1 General Tab

General Tab

The General tab collects basic wall geometry, soil values, and certain design assumptions.



4.1.1 General Data

General Data

Retained Height:

This is the height of retained earth measured from top of footing to the top of soil behind the stem (over the heel). When the backfill is sloped, the soil will slope away and upwards from this height.

The actual retained height used for overturning and soil pressure calculations will be the retained height projected at the vertical plane of the back of the heel, but for stem moments, no such increase will be made.

Using the spin-buttons you can vary this in 0.25-foot increments (or you can type in any number). After each entry you can press the tab key to advance to the next entry, or use your mouse to position the cursor in the next input field.

Wall Height above Retained Soil:

Use this entry to specify if the wall extends above the retained height. This entry is typically used to define a "screen wall" projection. This extension can be used as a weightless "Fence" or a concrete or masonry stem section without any soil retained behind it. You can enter wind load on this projection using the entry "Wind on Stem above soil" on the "Loads" tab. We'll handle the fence when we get to the STEM design screen. TOTAL HEIGHT OF WALL = “RETAINED HEIGHT” + WALL HEIGHT ABOVE RETAINED SOIL”.

Height of Soil over Toe:

Measured from top of footing to top of soil on toe side, this may vary from a few inches to a few feet depending upon site conditions. (Note that it is input in inches.) It is used to calculate passive soil resistance (but its effective depth can be modified by the "Ht. to Neglect" entry on the Footing > Key Dimensions & Sliding tab). This depth of soil is also used to calculate a resisting moment, and reduce net lateral sliding force. You can negate the latter effects on the Options screen.

Soil Slope:

You may enter any backfill slope behind the wall. Use the drop-down menu or type the slope as a ratio in the form of Horiz/Vert. The soil must be level or slope upward. Negative backfill slopes (grade sloping downward, away from the wall) are not allowed.

The program will use this slope to 1) include the weight of a triangular wedge of soil over the heel as vertical load, and 2) compute overturning based upon an assumed vertical plane at the back face of the footing extending from the bottom of the footing to ground surface – a steeper slope will result in a higher overturning moment. The program will not accept a backfill slope steeper than the angle of internal friction.

When the EFP method is used, the program will NOT change the EFP based on soil slope. All it does with the slope is:

- calculate the retained height at the back of the heel, which might be greater because of the sloped soil, and
- add a surcharge due to the weight of the triangular prism of soil on top.

When the Coulomb method is used, the final calculated pressures do include the effect of the slope on those Coulomb equations.

Water Table Height over Heel:

If a portion of the retained height is below a water table, the active pressure of the saturated soil will increase below that level. This additional pressure for the saturated soil is equal to the pressure of water, plus the submerged weight of the soil (its saturated weight - 62.4), plus the surcharge of the soil above the water table. The program does not collect a saturated weight of soil, so instead it conservatively approximates the buoyant or submerged weight of a soil as 65% of its dry unit weight.

If you want to design for a water table condition, enter the maximum height from ***bottom*** of footing to water table level. The program will then compute the added pressures for saturated soil on the heel side of the footing, including buoyancy effect, to calculate increased moments and shears on the stem, and overturning. Don’t enter a height more than the retained height, and keep in mind that this feature automatically assumes that the liquid is water. If the water table is near the top of the retained height, it may be advisable to use the saturated soil density and active pressure for the full retained height instead of specifying a water table height.

Top Lateral Restraint Height:

This will appear if you are designing a restrained wall. Enter the distance from the bottom of the stem to the point of lateral restraint.

4.1.2 Soil Values

Soil Values

Allowable Soil Bearing:

The maximum allowable soil bearing pressure for static conditions. Using the spin buttons you can vary the value in increments. Usual values for this vary from 1,000 psf to 4,000 psf or more.

Lateral Pressure Method:

Here you can choose between E.F.P. or Coulomb formula. EFP refers to "Equivalent Fluid Pressure," where you can enter a lateral soil pressure in psf per foot of depth. "Coulomb" instructs RetainPro to use the Coulomb method to calculate active and passive soil pressures using an entered angle of internal friction for the soil. When Coulomb is chosen, the Ka*Density value for active pressure is computed.

When the EFP Method is selected:

Active Soil Pressure - Heel Side:

Enter the equivalent fluid pressure (EFP) for the soil being retained that acts to overturn and slide the wall toward the toe side. This pressure acts on the stem for stem section calculations, and on the total footing+wall+slope height for overturning, sliding, and soil pressure calculations.

Commonly used values, assuming an angle of internal friction of 34°, are 30 pcf for a level backfill; 35 pcf for a 4:1 slope; 38 pcf for a 3:1 slope; 43 pcf for a 2:1 slope; and 55 pcf for a 1.5:1 slope. These values are usually provided by the geotechnical engineer.

When the EFP method is used the value entered is the horizontal component of the active earth pressure, commonly called the lateral earth pressure. Because active pressure is always due to an active soil wedge there are horizontal and vertical components. Using the specified horizontal component and the soil density, the program iterates for a value of an effective soil friction angle (“Phi”, the angle of internal friction) using the Coulomb equation. Once Phi is known, the program can calculate a vertical component of the active pressure and provide options to have this vertical component applied at the plane of retained earth, which is always considered to be at the rear of the heel. The user can choose to apply this force for overturning resistance, sliding resistance, and/or for soil pressure calculations, by checking the boxes in the category named "Use of vertical component of active lateral soil pressure".

Passive Pressure:

This is the resistance of the soil in front of the wall and footing to being pushed against to resist sliding. Its value is in psf per foot of depth (pcf). This value is usually obtained from the geotechnical engineer. Its value usually varies from 100 pcf to about 350 pcf.

Soil Density (heel side):

Enter the soil density for all earth (or water if applicable) above the heel of the footing. This weight is used to calculate overturning resistance forces and soil pressures using the weight of the soil block over the projecting heel of the footing. When surcharges are applied over the soil, the surcharges are transformed to equivalent uniform lateral loads acting on the wall by the ratio force = (Surcharge/ Density)*Lateral Load. Input this value in lbs. per cubic foot. Usual values are 110 pcf to 120 pcf. More if saturated soil. Water is usually assumed to be 64 pcf.

Soil Density (toe side):

Enter the soil density on the toe side, which may be different than the heel side. When surcharges are applied over the soil on the toe side, the surcharge is transformed to equivalent uniform lateral loads acting on the wall by the ratio force = (Surcharge/ Density)*Lateral Load. Input this value in lbs. per cubic foot. Usual values are 110 pcf to 120 pcf.

<u>When the Coulomb Method is selected:</u>

Soil Friction Angle:

This value is entered in degrees and is the angle of internal friction of the soil. This value is usually provided by a geotechnical engineer from soils tests, but can also be found in reference books or building codes for various typical soil classifications. This value is used along with Soil Density within the standard Coulomb equations to determine "Ka" and "Kp" multipliers of density to give active and passive soil pressure values.

Active Pressure (or At-Rest Pressure for Restrained Walls):

This value will be computed using the Coulomb formulas. This represents the lateral earth pressure acting to slide and overturn the wall toward the toe side. The result will be presented in units of psf/ft. This pressure acts on the stem for stem section calculations, and on the total footing+wall+slope height for overturning, sliding, and soil pressure calculations.

When the retained soil is sloped, a vertical component of the lateral earth pressure over the heel can be applied vertically downward in the plane of the back of the footing. You can choose to apply this force for overturning resistance, sliding resistance, and/or for soil pressure calculations, by checking the boxes on the Options tab.

Passive Soil Pressure:

This value will also be computed using the Coulomb formulas. This is the resistance of the soil in front of the wall to being pushed against to resist sliding. Its value is in psf per foot of depth (pcf). Common values usually vary from 100 pcf to about 350 pcf.

Soil Density (heel side):

Enter the soil density for all earth (or water if applicable) above the heel of the footing. This weight is used to calculate overturning resistance forces and soil pressures using the weight of the soil block over the projecting heel of the footing. When surcharges are applied over the soil, the surcharges are transformed to equivalent uniform lateral loads acting on the wall by the ratio force = (Surcharge/ Density)*Lateral Load. Input this value in lbs. per cubic foot. Usual values are 110 pcf to 120 pcf. More if saturated soil. Water is usually assumed to be 64 pcf.

Soil Density (toe side):

Enter the soil density on the toe side, which may be different than the heel side. When surcharges are applied over the soil on the toe side, the surcharge is transformed to equivalent uniform lateral loads acting on the wall by the ratio force = (Surcharge/ Density)*Lateral Load. Input this value in lbs. per cubic foot. Usual values are 110 pcf to 120 pcf.

4.1.3 Use of Vertical Component

Use of Vertical Component

Use of vertical component of active lateral soil pressure

This category offers the following three options for considering the vertical component of active lateral soil pressure:

- Use for Soil Pressure
- Use for Sliding Resistance
- Use for Overturning Resistance

When used, the vertical component of the lateral pressure is applied at a vertical plane at the back of the footing as follows:

When EFP is used, the program will backsolve the Coulomb equation to find the equivalent internal friction angle, phi. When the Coulomb method is used, the phi angle is specified by the user.

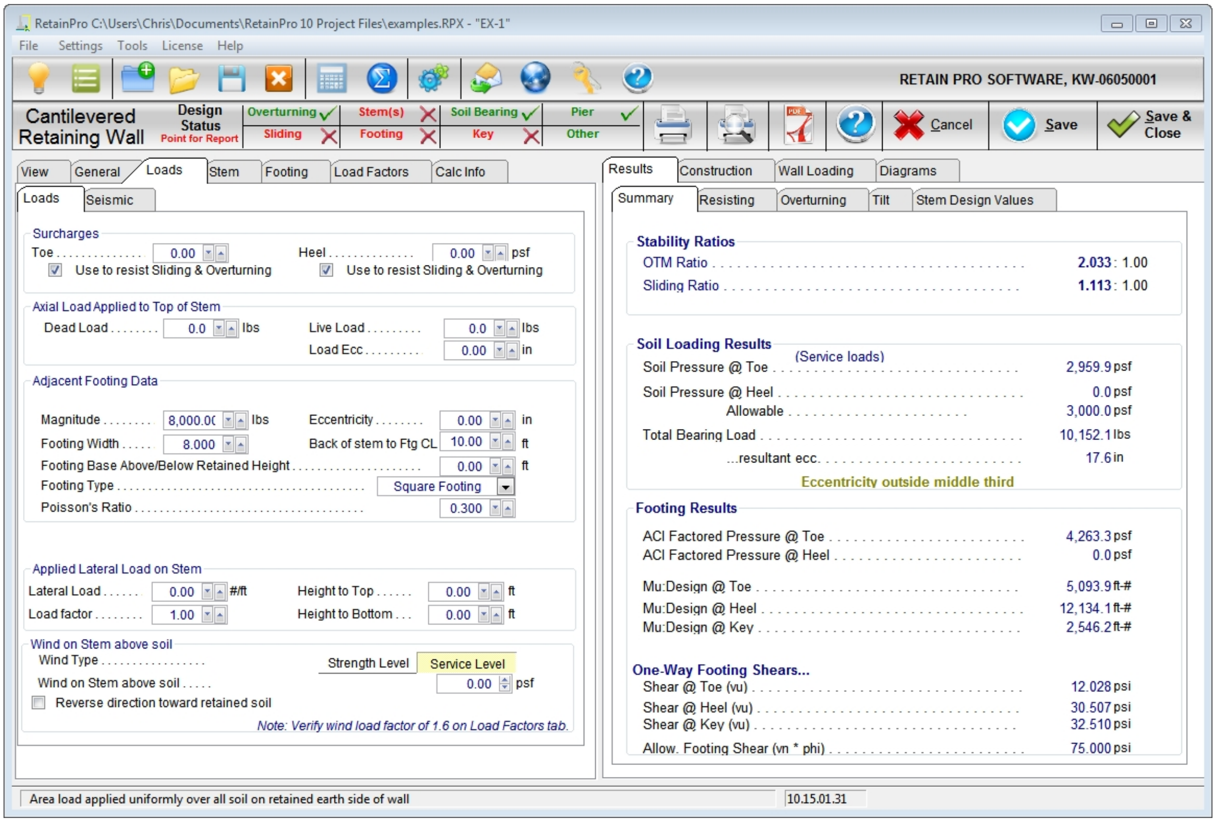
In configurations where there is **no** heel projection beyond the soil face of the stem, the failure plane is assumed to be at the soil-wall interface, so the program uses phi/2 for the soil-wall friction angle.

In configurations where there **is** a heel projection beyond the soil face of the stem, the failure plane is assumed to be at the end of the heel, which will be a vertical plane up through the soil. This will be a soil-on-soil interface, so the program uses phi as the friction angle to determine the vertical component.

4.2 Loads Tab

Loads Tab

The Loads tab collects the data required to define the applicable vertical and lateral loads, and the seismic design criteria, if applicable.



4.2.1 Loads

Loads

Surcharges

This surcharge is treated as additional soil weight – if the surcharge is 240 psf and the density is 120 pcf, then the program uses two feet of additional soil. Similarly, if 50 psf is added for the weight of a slab over the footing, this will be equivalent to 0.41 feet of soil (50 / 120). This surcharge will affect sliding resistance and passive pressure at the toe. Consider this if modeling a point load toe surcharge.

When a heel surcharge is defined, it is considered to be uniformly applied to the top surface of the soil over the heel. It may be entered whether or not the ground surface is sloped. This surcharge is always taken as a vertical force. This surcharge is divided by the soil density and multiplied by the Active Pressure coefficient to create a uniform lateral load applied to the wall. You can choose to use this surcharge to resist sliding and overturning by checking the option box adjacent to the load input field. Typical live load surcharges are 100 psf for light traffic and parking, and 250 psf for highway traffic.

Both the toe surcharge and the heel surcharge have associated checkboxes that can be used to dictate whether the respective surcharges should be considered as resisting sliding and overturning of the wall.

Axial Load Applied to Top of Stem

These loads are considered uniformly distributed along the length of the wall. They are applied to the top of the topmost stem section. The dead and live loads are used to calculate stem design values and factored soil reaction pressures used for footing design. Only the dead load is used to resist overturning and sliding of the retaining wall. AVOID A HIGH AXIAL LOAD (say over 3 kips plf Total Load) SINCE IT COULD CAUSE A REVERSAL OF BENDING IN THE HEEL.

Since slenderness ratios (h/t) for retaining walls are generally small, usually less than 10, and axial stresses are low, slenderness effects are checked but usually have a small effect.

Consider a point load (such as a beam reaction) applied to the top of a wall. The intensity of that point load will decrease at locations that are more distant from the point of application, because the lateral distribution width will increase as one moves away from the point of application. For this reason, the intensity of the axial load felt at the base of the stem will be significantly less than the intensity immediately beneath the beam bearing. To account for this effect, the magnitude of the axial point load entered should be reduced proportionately (since the input actually represents a uniformly distributed load along the length of the wall). But the top of the wall may need to be checked for localized stress by appended calculations.

The input for axial load applied to the top of the stem allows the load magnitudes to be defined as either Dead Load or Live Load. The load will be factored accordingly. This type of load also allows the specification of an eccentricity value, where the eccentricity is defined with respect to the centerline of the uppermost stem section. Positive values of eccentricity move the load toward the toe, causing bending moments that are additive to those caused by the lateral soil pressure over the heel. Negative eccentricities are accepted in the Restrained Retaining Wall module, where tension is already expected on the toe side. But negative eccentricities are not accepted in the Cantilevered Retaining Wall module.

Adjacent Footing Data

This entry gives you the option of placing a footing (line or square) adjacent and parallel to the back face of the wall, and have its effect on the wall included in both the vertical and horizontal forces on the wall and footing. Refer to the Reference Diagram for locations where input measurements should be taken.

Adjacent Footing Loads will be factored by the Live Load factor for strength design.

For "Line (Strip) Load" the entry is the total load per ft. parallel to the wall (not psf).

If the adjacent footing is specified as "Square Footing" (not line load), the load entered should be the adjacent footing load divided by its dimension parallel to the wall, giving a pounds per lineal foot value, as for a continuous (line) footing.

A Boussinesq analysis is used to calculate the vertical and lateral pressures acting on the stem and footing. The program uses equation (11-20a) in Bowles' *Foundation Analysis and Design*, 5^{th} Edition, McGraw-Hill, page 630.

When the Boussinesq analysis is used, the program may require additional computing time (hundreds of internal calculations are done after each entry), depending upon the speed of your computer. To avoid this delay (which occurs any time any entry is changed) we suggest you use a vertical load of zero until your data entry is nearly finalized. Then enter the actual footing load and modify your final values.

For adjacent truck or highway loading, it may be preferable to use a heel surcharge (uniform) of 250 psf (or more) instead of treating it as an "adjacent footing."

It is generally not necessary to use this feature if the adjacent footing load is farther from the stem than the retained height, less the depth of the adjacent footing below the retained height, since at this distance it will not have significant effect on the wall.

Footing Width: Width of the adjacent footing measured perpendicular to the wall.

This is necessary to create a one-foot long by Width wide area over which the load is applied.

Footing Eccentricity: This entry is provided in case the soil pressure under the adjacent footing is not uniform. Enter the eccentricity of the resultant force under the adjacent footing from the centerline of the adjacent footing. Positive eccentricity is toward the toe, resulting in greater pressure at the side of the adjacent footing closest to the stem. (An eccentricity value of zero means that the adjacent footing load will be considered to act at the center of the adjacent footing.) The program will use the vertical load and eccentricity and create a trapezoidal pressure distribution under the adjacent footing for use with the Boussinesq analysis of vertical and lateral pressures.

Wall to Footing Centerline Distance: This is the distance from the center of the adjacent footing to the back face of the stem at the retained height. The nearest edge of the footing should be at least a foot away from the wall face – otherwise suggest using an equivalent heel surcharge instead. Do not use a horizontal distance greater than the vertical distance from the top of the footing to the bottom of the adjacent footing, since the effect on the wall will be insignificant.

Footing Type: This drop down menu selection allows you to enter either an isolated footing using the "Square Footing" selection, or a continuous footing using the "Line Load" selection.

Footing Base Above/Below Retained Height: Use this entry to locate the bottom of the adjacent footing with respect to the Retained Height. Entering a negative number places the footing below the elevation of the soil measured at the back of the wall. A positive entry would typically only be used when the soil is sloped and the footing resides "uphill" from the retained height elevation. To insert a negative number, first type the number, then press the "-" (minus) sign.

Note: If the "Adjacent Footing" is another retaining wall at a higher elevation, the Boussenesq analysis may be used for the vertical load applied to the soil from the adjacent retaining wall footing, however the design must also consider the lateral (sliding) loads from that adjacent wall. This load could be applied as "Added Lateral Load", however this is at the discretion of the designer and is not within the scope of the program. <u>Caution is urged for this condition</u>. See discussion in the companion book: Basics of Retaining Wall Design. *The designer should be advised that the program does not incorporate any form of global stability analysis.*

Poisson's Ratio: Since the resulting pressures are sensitive to Poisson's Ratio, there is an entry allowing you to specify a ratio from 0.30 to 0.55. This value should be provided by the geotechnical engineer. A value of 0.50 is often assumed.

Applied Lateral Load on Stem

This input allows you to specify an additional uniformly distributed lateral load applied to the stem. <u>This is generally not the preferred method of applying seismic load. Use the Seismic sub-tab instead.</u>

This entry can be useful for a point load, such as due to an impact of a car or similar force. When used in this way, it may be easiest to enter the load as a one-foot high increment, and specify the "Height to Bottom" and "Height to Top" to define a one-foot high strip of application.

<u>This load will be factored by whatever value is specified in the adjacent Load factor input.</u> To apply an additional factor (such as an impact factor), increase the applied load proportionately (e.g. an impact load of 1000 lbs requiring an impact factor of 2.0

would be entered as 2,000 lbs). You may need to do several designs to check multiple load combinations.

Use engineering judgment when applying a point lateral load. The magnitude may be able to be reduced to account for the fact that the load distributes horizontally at levels below the point of application, so its intensity reduces at elevations below the point of application.

Height to Top: defines the upper extent of the applied lateral load measured from the top of the footing. Do not enter a dimension higher than the top of the wall ("Retained Height" plus "Wall height above retained soil").

Height to Bottom: defines the lower extent of the applied lateral load measured from the top of the footing.

Load Factor: will be applied to the lateral load when performing strength design checks. It is not applied for service level load checks such as sliding, overturning, or soil bearing pressure checks.

Wind on Stem above Soil: will be applied to that part of the stem projecting above the retained height defined by the entry "Wall height above retained soil." It is used to generate sliding force, overturning moment, stem design moment and shear, and soil pressures. There will be a check box to indicate whether you wish to apply the wind in a reverse direction. Use this with caution since it may not capture the most critical design condition. (i.e., it will cause the program to skip the condition where the wind force would combine with the soil overturning force.)

Wind Type: Note that recent building codes have started to determine wind forces at the strength level as opposed to at the traditional service level. Consequently RetainPro allows the user to indicate whether the specified wind pressure is at the Strength-Level or at the Service-Level.

When performing a design based on IBC 2012 / CBC 2013 or later:

- The wind should be entered as a Strength-Level load.
- When designing a masonry stem by strength design methodology or a concrete stem, the wind load factor (which should be 1.0) will be applied to the specified wind loads.

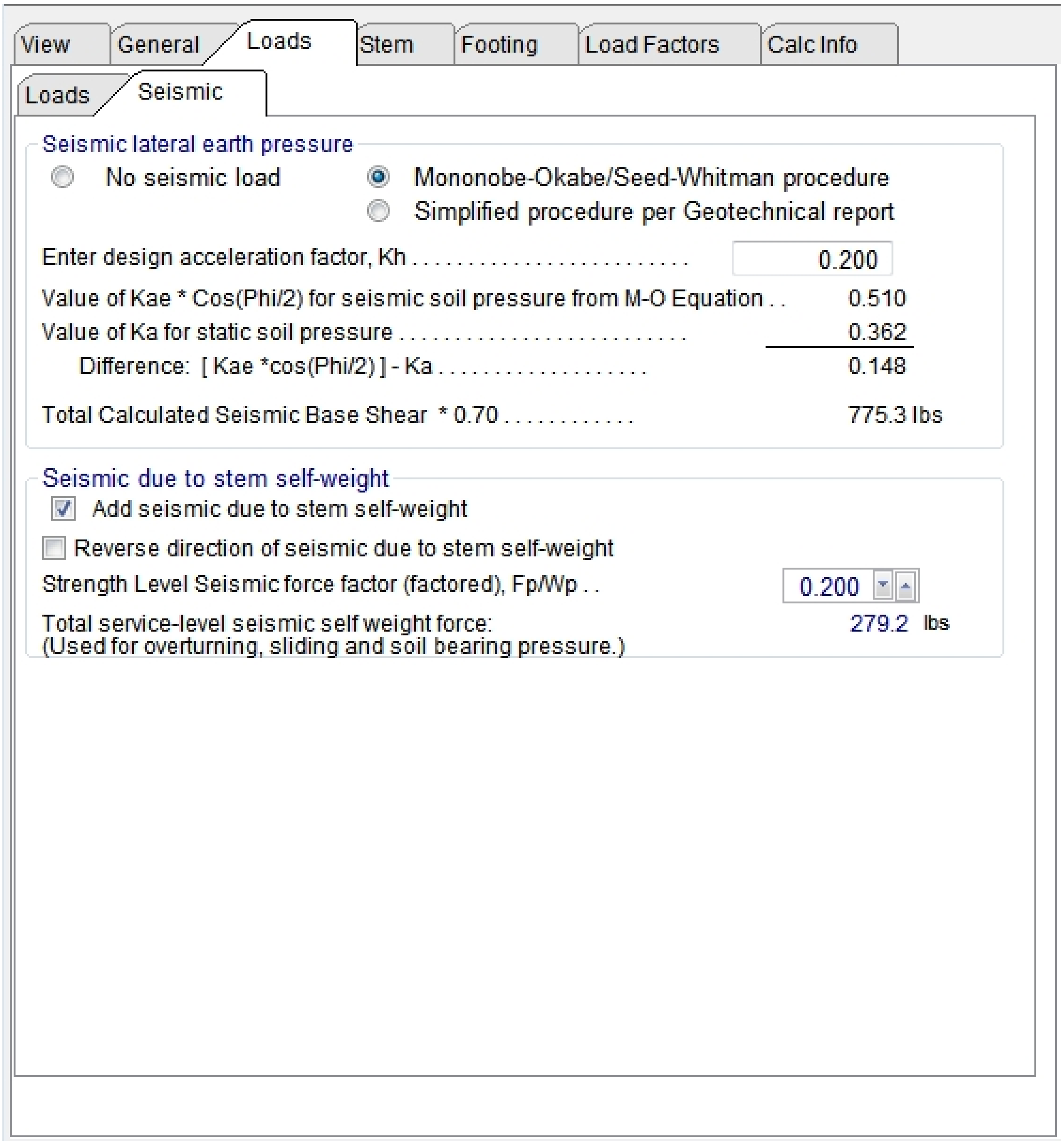
- When designing a masonry stem by ASD methodology, the wind load factor is not used, and the specified wind loads will be reduced to a service level by multiplying the specified pressure by 0.6.
- Regardless of the stem construction, when determining service-level soil bearing pressure and when performing sliding and overturning checks, the specified wind loads will be reduced to a service level by multiplying the specified pressure by 0.6.

When performing a design based on codes *earlier than* IBC 2012 / CBC 2013:

- The wind should be entered as a Service-Level load.
- When designing a masonry stem by strength design methodology or a concrete stem, the wind load factor (which should be 1.6) will be applied to the specified wind loads.
- When designing a masonry stem by ASD methodology, the wind load factor is not used, and the specified wind loads will be used exactly as specified.
- Regardless of the stem construction, when determining service-level soil bearing pressure and when performing sliding and overturning checks, the specified wind loads will be used exactly as specified.

4.2.2 Seismic Loads

Seismic Loads



You can choose to apply seismic force from lateral earth pressure and/or from wall self-weight.

Seismic Lateral Earth Pressure

This category is used to specify whether seismic lateral earth pressure is to be considered or not. If it is to be considered, the program offers the option of two different methods:

- Mononobe-Okabe/Seed-Whitman procedure, or

- Simplified procedure per Geotechnical report

Mononobe-Okabe/Seed-Whitman Procedure

By entering k_h the program will calculate K_{AE} and K_A using the Mononobe-Okabe/Seed-Whitman equations for a yielding wall (cantilevered).

If it is a non-yielding wall (restrained) the added lateral force per square foot is computed using $F_w = k_h$(density)(retained height), in psf. Common k_h values range from 0.05 to 0.30, depending upon area seismicity. Some sources indicate that $k_h = S_{DS} / 2.5$, but jurisdictions and interpretations vary.

Both the static soil pressure component and the added seismic component will be displayed. The resultant seismic component is assumed to act at 0.6 x retained height. The seismic component is assumed to vary from an intensity of X at the bottom of footing to an intensity of 4X at the top of the retained height.

Mononobe-Okabe/Seed-Whitman Methodology

Two excellent references on the subject include *Basics of Retaining Wall Design* 11th Edition by Hugh Brooks https://www.amazon.com/Basics-Retaining-Wall-Design-11th/dp/0976836475 and *Seismic Earth Pressures on Deep Building Basements* by Lew, et al.

The program computes K_{AE} (coefficient for combined active and earthquake forces) per the Coulomb formula, modified by Mononobe-Okabe/Seed-Whitman, to account for earthquake loading, where the term θ is the angle whose tangent is the horizontal ground acceleration. (Note that if $K_h = 0$, $\theta = 0$, then $K_{AE} = K_A$.) Vertical acceleration is neglected, resulting in a more conservative K_{AE}.

K_{AE} = active earth pressure coefficient, static+seismic

$$= \frac{\sin^2(\alpha + \theta - \phi)}{\cos\theta' \sin^2\alpha \sin(\alpha + \theta + \delta)\left[1 + \sqrt{\frac{\sin(\phi + \delta)\sin(\phi - \theta - \beta)}{\sin(\alpha + \delta + \theta)\sin(\alpha - \beta)}}\right]^2}$$

Where $\theta = \tan^{-1} K_h$, α = wall slope to horizontal (90 degrees for a vertical face), ϕ = angle of internal friction, β = backfill slope, and δ = wall friction angle.

For a vertical wall face and δ assumed to be $\phi/2$, K_{AE} becomes:

$$K_{AE} = \frac{\sin^2(90+\theta-\phi)}{\cos\theta \sin^2 90 \sin(90+\theta+\phi/2)\left[1+\sqrt{\frac{\sin 1.5\phi \sin(\phi-\theta-\beta)}{\sin(90+\phi/2+\theta)\sin(90-\beta)}}\right]^2}$$

The values K_{AE} and K_A are displayed.

For the horizontal component, the forces are multiplied by cos δ (wall/soil interface angle).

Total force (active and seismic) = P_{AE} = $0.5(\gamma)\ K_{AE}\ H^2$ where γ = soil density and H = retained height.

Since the total force P_{AE} consists of two components, static (P_A, as previously computed for static forces) with triangular distribution and the earthquake (P_{AE} - P_A) with an inverted semi-triangular distribution with an assumed point of application at 0.60 x height, the combined (static and EQ) point of application is determined by

$$\bar{y} = \frac{P_A(H/3) + (P_{AE} - P_A)\ 0.6H}{P_{AE}}$$

which is displayed as "Ht. to static + EQ point of appl."

Total base shear for both static force and added seismic force are displayed.

From *Seismic Earth Pressures on Deep Building Basements* by Lew, et al:

If the Mononobe-Okabe analysis is used to determine the lateral seismic earth pressure, the lateral earth pressure should consist of the static active earth pressure and the seismic increment of earth pressure as discussed in the previous section. Presumably, the load factor of 1.6 in Eq. (8) would be applicable to the total earth pressure in this case. However, as noted above, a reduced load factor would be appropriate when considering the transitory nature of the seismic component and the low likelihood of the load maxima occurring simultaneously. Accordingly a lower load *factor of 1.0 is proposed to be applied to the seismic increment component of earth pressure while the 1.6 load factor is applied to the static active pressure component. To facilitate such loading combination the geotechnical engineers would have to separate earth pressure components attributable to the active earth pressure condition and the seismic increment of earth pressure when using the M-O method*.

Simplified procedure per Geotechnical report

Use this method if a geotechnical report specifies added seismic load as a factor multiplied by the retained height, such as X*H, where X is the multiplier and H is the retained height, enter that multiplier here. Using this method, the seismic lateral force will be applied uniformly over the retained height. Since this is a factored force it will be reduced by 0.7 for use in sliding, overturning, and soil bearing calculations.

Seismic due to stem Self-Weight

If you indicate that you want the program to consider the seismic effect due to the self-weight of the stem, then you will specify a value for the factor Fp/Wp, which will be used to calculate a uniform seismic force in psf (k_h x (wall weight). If the wall has multiple stem sections, each will be calculated separately and accumulated for the base shear and moment.

NOTE: The k_h values entered are the design accelerations (not necessarily peak ground acceleration as may be given in a geotechnical report) and must be determined per procedures in the applicable code. The program then applies the appropriate Load Factors (1.0 for concrete design and 0.7 for serviceability checks).

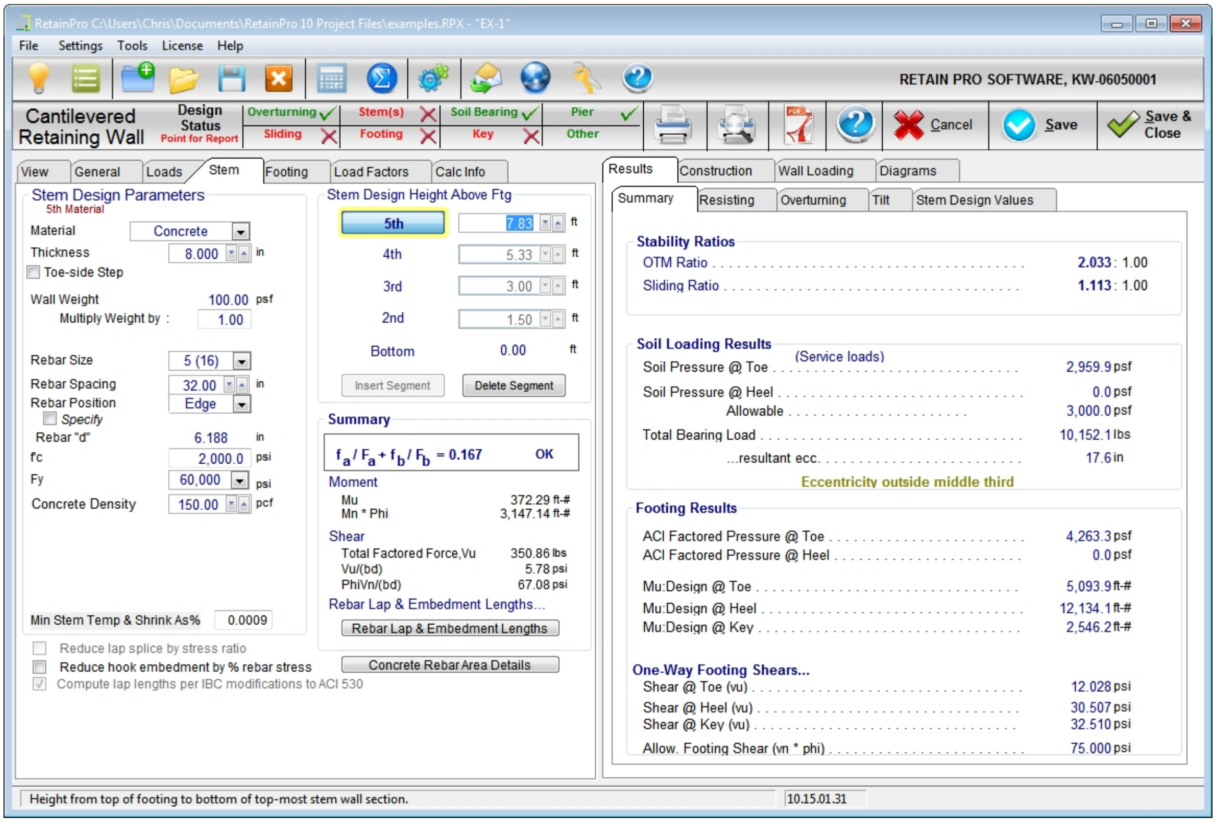
There is a check box to allow the applied seismic force to be reversed to that it acts in the direction that opposes the active lateral earth pressure. Use caution with this option, since it has the effect of reducing the magnitude of total load applied to the retaining wall system.

4.3 Stem Tab

Stem Tab

The Stem tab collects the data required to define the stem geometry, reinforcing, and design heights.

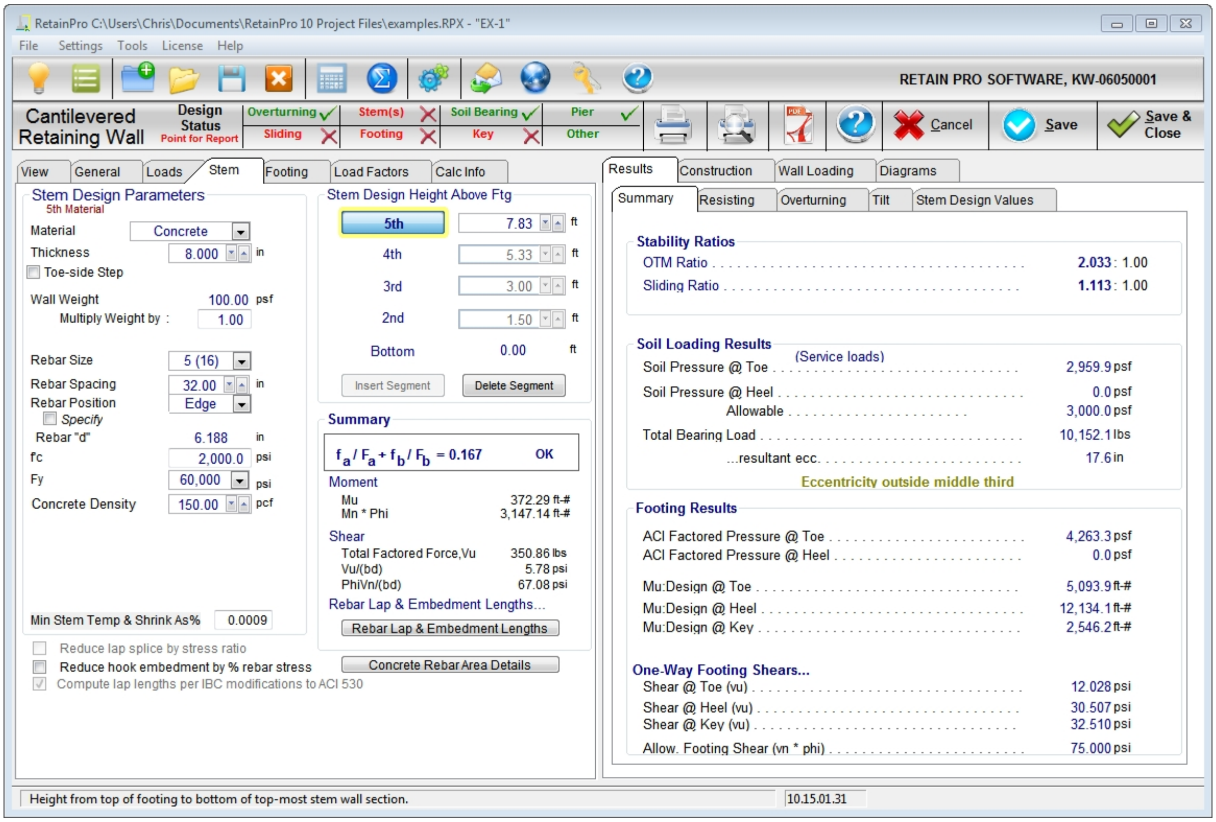
The layout and content of this tab will vary depending upon which type of wall is being designed. Refer to the subsequent topics in this section of the User's Manual for wall-specific details on the various parameters that are collected on this tab.



4.3.1 Stem Tab for Cantilevered Retaining Wall

Stem Tab for Cantilevered Retaining Wall

When a Cantilevered Retaining Wall is defined, the Stem tab will appear as shown below:



Stem Design Parameters

Material: Use the drop-down list box to select Masonry, Concrete, Fence, or None. Fence is only allowed on top of the wall, higher than the Retained Height, and is considered weightless. Use None to disable the stem section.

Thickness: Use the spinners to set the thickness of Concrete wall segments. Use the drop-down list box to set the thickness of Masonry wall segments. For segments defined as "Fence" the thickness input is unavailable.

Wall Weight: This displayed value is based upon wall data within the program. A multiplier input field is provided if it becomes necessary to adjust the data. See Appendix C for masonry wall weights.

Design Method: When a masonry stem section is chosen, this allows a choice of ASD or LRFD (Allowable Stress Design or Load and Resistance Factor Design). When the latter is selected the input notations change (e.g. f_s to f_y) and all calculations are based upon LRFD.

Rebar Size: Make your selection from the drop-down list box for bar sizes #3 to #10. “Soft Metric” sizes will be displayed in parentheses.

Rebar Spacing: Use the spinners to set the rebar spacing in Concrete wall segments. Use the drop-down list box to set the rebar spacing in Masonry wall segments. For segments defined as "Fence" the rebar spacing input is unavailable.

Rebar Position: Chose between Center or Edge. If Center is chosen, the rebar d distance will be 1/2 the actual wall thickness. If Edge is chosen the rebar will be located at the heel side of the stem as defined below.

For masonry wall segments, the program contains a table of the appropriate "d" values to use for various block sizes and center/edge locations, as shown in the table below.

Default Values of Rebar Position for Masonry Wall Segments

Thickness	**Rebar Depth (in)**	
	Center	**Edge**
6"	**2.75"**	**2.75"**
8"	**3.75"**	**5.25"**
10"	**4.75"**	**7.25"**
12"	**5.75"**	**9.0"**
14"	**6.75"**	**11.0"**
16"	**7.75"**	**13.0"**

For concrete wall segments, the "edge" rebar depth is always stem thickness less 1.5" for #5 and smaller bars (stem thickness less 2" for #6 or larger), less one-half the bar diameter.

Specify Position : Click this box to enter an explicit "d" value for the particular stem segment.

f'm: For Masonry stem segments, enter the compressive strength of masonry in units of psi. This input is not applicable to Concrete stem segments.

f'c: For Concrete stem segments, enter the compressive strength of concrete in units of psi. This input is not applicable to Masonry stem segments.

F_s: For ASD masonry design, select the allowable steel stress, based on working stress design, which should be used for design of the masonry stem segment. The drop-down list box allows quick selection of common values. This input is not applicable to LRFD masonry design or to concrete design.

Fy: For LRFD masonry design and for concrete design, select the rebar yield stress to used for design of the indicated stem segment. The drop-down list box allows quick selection of common values. This input is not applicable to ASD masonry design.

CMU weight type: (Applies to Masonry stem segments only.) This input provides a drop-down list box that offers the common CMU weights.

Concrete Density: (Applies to Concrete stem segments only.) This input provides spinners to define the unit weight of the concrete for a particular stem segment.

Solid Grouting: This applies to masonry only, and if this box is checked the weight of the wall will be based upon industry standard values for the weights of solid-grouted walls of lightweight, medium weight, or normal weight block based on the selection for CMU weight type.

If this box is not checked, the program will calculate the weight based upon grouting of only cells containing reinforcing.

This also affects equivalent solid thickness for stem shear calculations, and area for axial stress calculations (combined with moment for masonry stems).

Em = f'm *: This input collects the value by which the compressive strength of masonry is multiplied to arrive at the value of the modulus of elasticity for masonry. IBC '06 specifies E_m = 900*f'$_m$ which is the default value.

"n", Modular Ratio: This is calculated by the program as Es/Em.

Equivalent Solid Thickness: For partially-grouted masonry stem segments (those where solid grouting has not been specified) the equivalent solid thickness is generated from an internal database as shown below:

	Grout Spacing					
Thickness (inches)	***8"***	***16"***	***24"***	***32"***	***40"***	***48"***
6	***5.6***	***4.5***	***4.1***	***3.9***	***3.8***	***3.7***
8	***7.6***	***5.8***	***5.2***	***4.9***	***4.7***	***4.6***
10	***9.6***	***7.2***	***6.3***	***5.9***	***5.7***	***5.5***
12	***11.6***	***8.5***	***7.5***	***7.0***	***6.7***	***6.5***
14	***13.6***	***9.9***	***8.7***	***8.1***	***7.6***	***7.4***
16	***15.6***	***11.6***	***10.1***	***9.5***	***8.6***	***8.3***

Stem Design Height Above Footing: IMPORTANT! The term "Stem Design Height" refers to a height above the top of the footing (i.e. above the base of the stem). It is the height above the bottom of the stem where you want the program to compute moments and shears.

You can divide the stem into a maximum of five segments (increments of height). Each increment can represent a change in material (concrete, masonry, or fence), thickness, reinforcing size or spacing.

For most walls, only two or three changes in stem sections are used. For example, it would be logical to place a Stem Design Height at the top of the dowels projecting into the stem from the footing and perhaps at another location farther up the wall where a more economical section is desired.

Bottom: You must start your stem design here, at the base (height above footing = 0.00), where the stem moment and shear is maximum. You can manipulate the bar sizes, spacing, and position, as well as the wall material and thickness until the Summary box indicates an acceptable stress ratio (the higher and closer to 1.0, the more efficient).

To check the wall at a higher Design Height, such as at least the LAP REQ'D IF ABOVE distance, where reinforcing or thickness can be reduced, click the Insert Stem button and enter the next higher design height. Advance the spin button to the desired height above the top of the footing or enter it by typing. This will create a new 2nd section that you can now design.

Continue this way, clicking Insert Stem after each stem section design is completed, up to a maximum of five heights. A new Design Height should only be entered when you want to change the material, thickness, or reinforcing, and should never be less than about two-foot intervals.

Summary

The summary box indicates the design shears and moments in the selected stem segment, and the interaction ratio for that segment.

For stem segments of Masonry that are designed according to ASD, the Summary indicates actual and allowable moments, total applied shear force, applied shear stress and allowable shear stress, and rebar lap splice lengths.

For stem segments of Concrete or of Masonry that are designed according to LRFD, the Summary indicates factored applied moment and the nominal moment capacity, the total applied shear force, the factored applied shear stress and the nominal shear stress, and rebar lap splice lengths.

See additional detail in the section named "Summary Section of Stem Tab".

Design Options

The last section offers the following design options:

- Reduce lap splice by stress ratio (This option is provided for informational purposes only. Use engineering judgment with the application of this option, as it is contrary to current building codes and design standards.)
- Reduce hook embedment by % rebar stress
- Compute lap lengths per IBC modifications to ACI 530. As of build 10.14.7.15, this is automatically selected, because IBC is clear that this is mandatory.

4.3.1.1 Summary Section of Stem Tab

Summary Section of Stem Tab

The summary section indicates the results of the Stem design at-a-glance.

Interaction Ratio: The interaction ratio indicates the efficiency of your design, not to exceed 1.0.

For masonry using ASD this is the computed ratio of f_a/F_a + $M_{actual}/M_{allowable}$. For concrete and masonry using LRFD it is $M_{actual}/M_{allowable}$.

The weight of the stem will be included only if there is added axial load. For masonry stems, F_a is calculated by considering the wall as unsupported with "K" = 2.0. Since even a very small axial load will activate the unsupported height/slenderness calculation for masonry stems, we suggest you do not enter an axial load unless it is significant (e.g. greater than, say, 3000 plf.).

Actual Moment: This is the maximum moment due to the lateral pressures and applied loads above the "Design Height" location entered. Note that when concrete is used, all soil pressures and loads are factored per default Load Factors for evaluation of moments and shears.

Allowable Moment: This is the allowable moment capacity. It is Allowable Stress Design (ASD) for masonry, or based upon Strength Design for concrete and when LRFD is specified for masonry. For concrete strength design, the maximum reinforcing steel percentage is controlled by equilibrium at the prescribed strain limits.

Total Force: This is the total lateral force from loads applied above the "Check Design at Height" location entered. This force is factored for concrete and masonry using the LRFD method. Forces applied to compute overturning, sliding, and soil pressure are <u>not</u> factored.

Actual Shear: For masonry, the effective thickness is used to calculate the actual shear. The effective thickness is the actual "d" distance for the moment applied, considering partial or full grouting (equivalent solid thickness is not used). In other words, the unit shear is determined by dividing the total lateral force of the stem cross section by the product of "d" * 12" unit width strip. Shears are calculated at the "Design height" location entered, not at distance "d" above design height. Concrete stems use an area of "d" x 12" for the shear area, and masonry stems use "d" x 12" per ACI 530-11, Section 2.3.6.1.1.

Allowable Shear: For masonry designed by ASD according to ACI 530-11, the allowable shear stress varies between 3*sqrt(f'm) and 2*sqrt(f'm) as a function of M/(Vd). No contribution of shear strength is assumed from reinforcing steel in a retaining wall.

For masonry designed by LRFD according to ACI 530-11, the nominal shear strength varies between 6*Anv*sqrt(f'm) and 4*Anv*sqrt(f'm) as a function of M/(Vd). Again, no contribution of shear strength is assumed from reinforcing steel in a retaining wall.

For concrete, the nominal shear strength is 2*λ*sqrt(f'c), per ACI 318-05 Section 11.3.1.1 or ACI 318-08 Section 11.2.1.1 or ACI 318-11 Section 11.2.1.1.

Rebar Lap & Embedment Lengths: Regardless of the stem material, there are two fundamental lengths to calculate: lap splice length and development length. These values are summarized in the "Rebar Lap & Embedment Lengths" table, which can be accessed from the button on the Stem tab. As of build 10.14.7.29, this table is only available in the Cantilevered Retaining Wall module.

The following presents the formulas used and the limits applied to generate the values in that table:

<u>**Straight Development Length of Rebar in Concrete:**</u> (Applies to all referenced codes)

$\ell_{d\ calc}$ = (3/40) * (fy / sqrt(f'c)) * (psi_s / 2.5) * (bar size / 8)

psi_s = 0.8 for bar sizes #6 and smaller, 1.0 for bar sizes #7 and larger

$\ell_{d\ report}$ = $\ell_{d\ calc}$ but not less than 12 inches

(This is Eq. (12-1) with appropriate assumptions for bar location, clear cover, spacing, transverse reinforcing, and epoxy coating.)

Lap Splice Length of Rebar in Concrete:
(Applies to all referenced codes)

ℓ_s = 1.3 * $\ell_{d\ calc}$ but not less than 12 inches

Hooked Embedment of Rebar in Concrete:
(Applies to all referenced codes)

$\ell_{dh\ calc}$ = 0.02 * (fy / sqrt(f'c)) * (bar size / 8) * 0.7 * ($A_{s\ required}$ / $A_{s\ provided}$)

($A_{s\ required}$ / $A_{s\ provided}$) = the ratio of required to provided area of rebar (this is a user option checkbox)

$\ell_{dh\ report}$ = $\ell_{dh\ calc}$ but not less than the larger of 8 bar diameters or 6 inches

Development Length of Rebar in Masonry designed by ASD: (Applies to all referenced codes)

$\ell_{d\ calc}$ = (0.002) * (bar size / 8) * f_s

f_s = actual stress in rebar

$\ell_{d\ report}$ = $\ell_{d\ calc}$ but not less than 12 inches

(This is the IBC equation.)

Lap Splice Length of Rebar in Masonry designed by ASD: (Applies to all referenced codes)

ℓ_s = Factor * $\ell_{d\ calc}$ but not less than 12 inches or 40 bar diameters

Factor = 1.5 in regions where design tensile stresses in reinforcement are greater than 0.8 * f_s, otherwise 1.0.

(As of build 10.14.7.29, the program conservatively assumes a value of 1.5 for the "Factor" referenced above.)

Development Length of Rebar in Masonry designed by LRFD: (Applies to all referenced codes)

$\ell_{d\ calc}$ = (0.13) * (bar size / 8)^2 * fy * gamma / (K * sqrt(f'm))

gamma = 1.0 for #3 through #5 bars, 1.3 for #6 through #7 bars, and 1.5 for #8 through #9 bars

K = 1.5 for #3 through #5 bars, 2.0 for #6 through #9 bars

$\ell_{d\ report}$ = $\ell_{d\ calc}$ but not less than 12 inches

(This is the ACI equation by direct reference from IBC. The value of K has conservatively been set to the required clear cover for the selected bar exposed to earth.)

Lap Splice Length of Rebar in Masonry designed by LRFD: (Applies to all referenced codes)

$\ell_s = 1.0 * \ell_{d\ calc}$ but not less than 12 inches and need not be GREATER than 72 bar diameters

General Notes on Rebar Lap & Embedment Lengths:

For concrete stems, a Class B lap splice is assumed (see ACI 318-11, 12.15), therefore the lap length is the bar development length x 1.3. Concrete is assumed to be normal weight, and bars are assumed to be plain (not epoxy coated).

Concrete development lengths are computed per ACI 12.2.

For the bottom Design Height only (Ht. = 0.00), this displays the required hooked bar embedment into the footing. It assumes a bar with a 90° bend and at least a 12-diameter extension.

The minimum footing thickness required is based upon this embedment depth plus the clearance you have specified below the bar (usually 3 inches). If this totals more than the footing thickness you have chosen, a warning message will be displayed.

Note that if the bar extends straight down into a key, it must be embedded by a depth equal to the development length.

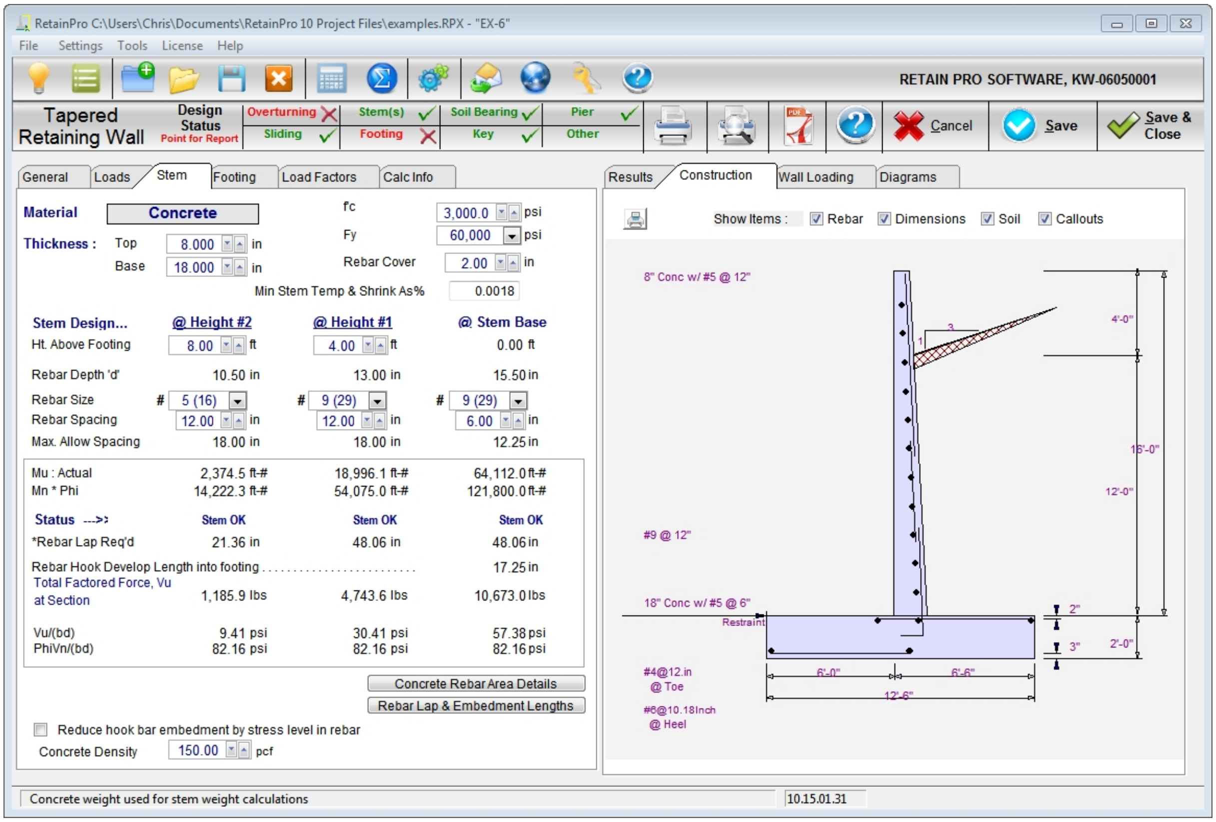
The program does not reduce embedment length by stress level unless the user selects the checkbox labeled Reduce Hook Embedment by Percent Rebar Stress.

The program never reduces lap splice lengths by the stress ratio. It is not permitted by the referenced codes.

4.3.2 Stem Tab for Tapered Stem Retaining Wall

Stem Tab for Tapered Stem Retaining Wall

When a Tapered Stem Retaining Wall is defined, the Stem tab will appear as shown below:



Note: Taper can only apply to the inside face (the face against the soil).

Material: The Material will automatically be defined as Concrete, since masonry cannot be tapered.

Thickness: Top and Base: Enter the stem thickness at the top and at the bottom.

f'c and Fy: Enter concrete strength and rebar yield stress.

Rebar Cover: Select the rebar clear cover to consider in the design.

Stem Design: Stem design will automatically be performed at the bottom of the stem (interface with the footing). In addition, you can specify two additional heights above the base to check moments and shears. These are identified as "@ Height #2" and "@ Height #1", where the latter is the lower height.

Ht. Above Footing: Specify two heights above the top of footing elevation where a stem design should be performed (such as where it would be desirable to change the rebar pattern or size for economy). Height #2 is highest and Height at Stem Base will be fixed at 0.00. The #1 height should be located at a distance above the top of the footing that is at least equal to the lap splice length for the dowels.

Rebar Depth "d": This will be computed based upon the heights you have chosen, the specified wall taper, and the specified Rebar Cover. (The calculation of Rebar Depth for a tapered stem uses a conservative approximation by assuming a dimension of one-inch for the rebar diameter, regardless of the size of rebar actually selected. Accordingly, the program will adjust the rebar depth by a value of one-half of an inch to determine "d".)

Rebar Size: Use the drop-down list box to select the desired rebar size.

Rebar Spacing: Use the spinners to set the desired rebar spacing. (The maximum permissible spacing is 18 inches, which is in accordance with ACI.)

Max. Permissible Spacing: This is the maximum permissible spacing for the rebar size selected. This is based on the strength calculation, but it will stop at an upper limit of 18 inches in accordance with ACI.

M_u: These are factored moments at the heights you have selected. These will be based on the load factors that you specify on the Load Factors tab. Compare these values with Design Moment as described below, to verify adequacy of your design at the selected height location.

ϕM_n: This is the design moment strength, which will be based upon the bar sizes and spacings you established, along with wall geometry, concrete strength, etc.

Status: This indicates whether each stem design is OK at the specified height. If there is a problem, this will display a descriptive message such as "M_u > Phi ∗ M_n" or "A_s < min" or "A_s > max" or "Ftg. Rebar Embed!".

Rebar Lap Req'd: This is the lap splice length required based on the bar size used at the specified Design Height. It is the development length of the bar multiplied by 1.3 (assuming a Class B splice) and without adjustment for stress level.

Rebar Hook Development Length into Footing: This is the hooked development length that is required for the bar size specified at the stem base. It is based on the assumption that the bar is hooked into the footing with a 90° bend and minimum 12 d_b bar extension. The calculated values is also based on the assumption that the side cover (normal to the plane of the hook) is not less than 2.5 inches and that the cover on the extension beyond the hook is not less than 2 inches. These latter assumptions facilitate the application of a factor of 0.7 to the calculated value of l_{dh}.

Shear at Section: This is the total factored shear at the indicated height.

V_u: Factored shear stress at designated height computed by Shear at Section / (12 ∗ "d").

ϕV_n: Design Shear Strength based upon 0.75 ∗ 2 ∗ sqrt(f'c) for concrete.

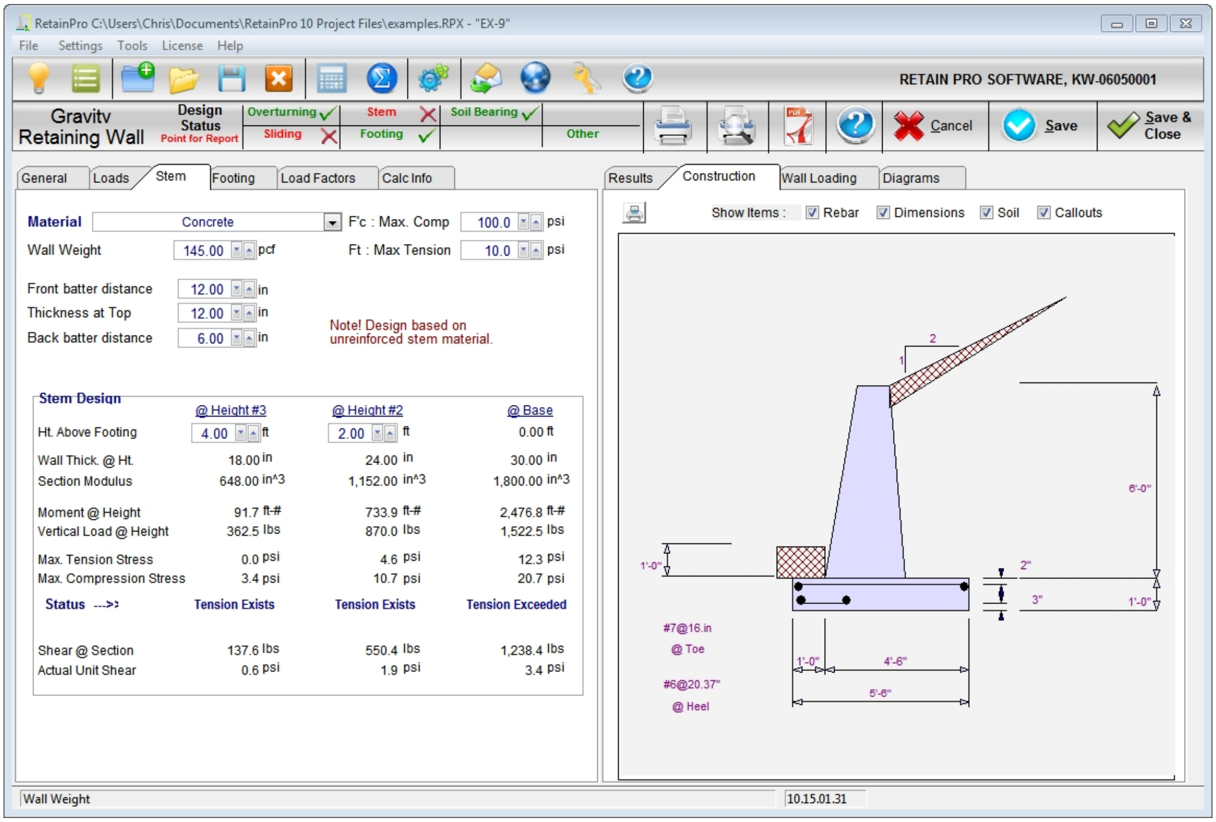
Option to reduce hooked bar embedment depth: When the checkbox is checked the program will reduce the hooked embedment depth by the considering the ratio of (As required)/(As provided).

Concrete Density: Use the spinners to set the unit weight of the concrete.

4.3.3 Stem Tab for Gravity Retaining Wall

Stem Tab for Gravity Retaining Wall

When a Gravity Retaining Wall is defined, the Stem tab will appear as shown below:



Gravity walls may have one or both sides tapered and are assumed to be proportioned such that no reinforcing is required since every section is primarily in compression. Any solid homogeneous material may be used. Reinforcing can be added if there is any tension in the cross section, but the program does not compute this requirement.

Material: Use this drop-down list box to specify the material being considered.

Wall Weight: Enter the weight of the wall material in pcf. Generally this will be the weight of concrete or rubble (approximately 145 pcf).

Front Batter Distance: Enter the offset of the front face at top of the wall from the front face at the base.

Thickness at Top: Enter the thickness of the top of the wall.

Back Batter Distance: Enter the offset of the back face at the top of the wall from the back face at the base.

F'c Max. Compression: Enter your criteria for the maximum permissible compressive stress on the wall. Usually varies from 100 psi to over 700 psi.

Ft Max. Tension: Enter your criteria for the maximum permissible tensile stress on the wall. Usually varies from about 15 psi to 40 psi. Generally gravity walls are designed such that there is no tension – the full cross section is in compression.

Stem Design

Stem design will automatically be performed at the bottom of the stem (interface with the footing). In addition, you can specify two additional heights above the base to check stresses. These are identified as "@ Height #2" and "@ Height #1", where the latter is the lower height.

Height Above Footing: Specify two heights above the top of footing elevation where stem stresses should be checked. Height #2 is highest and @Stem Base will be fixed at 0.00.

Wall Thickness @ Height: Displays the calculated values of wall thickness at the heights you have specified for analysis.

Section Modulus: Displays the computed section modulus at the heights selected for analysis.

Moment @ Height: Displays the moment at the designated design heights.

Vertical Load @ Height: Displays the summation of vertical loads above designated height.

Maximum Tension / Compression Stress: Displays extreme tension and compression stresses based on interaction formulas.

Status: Indicates "OK" if not tension exists. If tension exists but it does not exceed the user-specified threshold then the status indicates "Tension Exists". If tension exists to a degree that exceeds the user-specified threshold then the status indicates "Tension Exceeded". If compression exists to a degree that exceeds the user-specified threshold then the status indicates "Compression Exceeded".

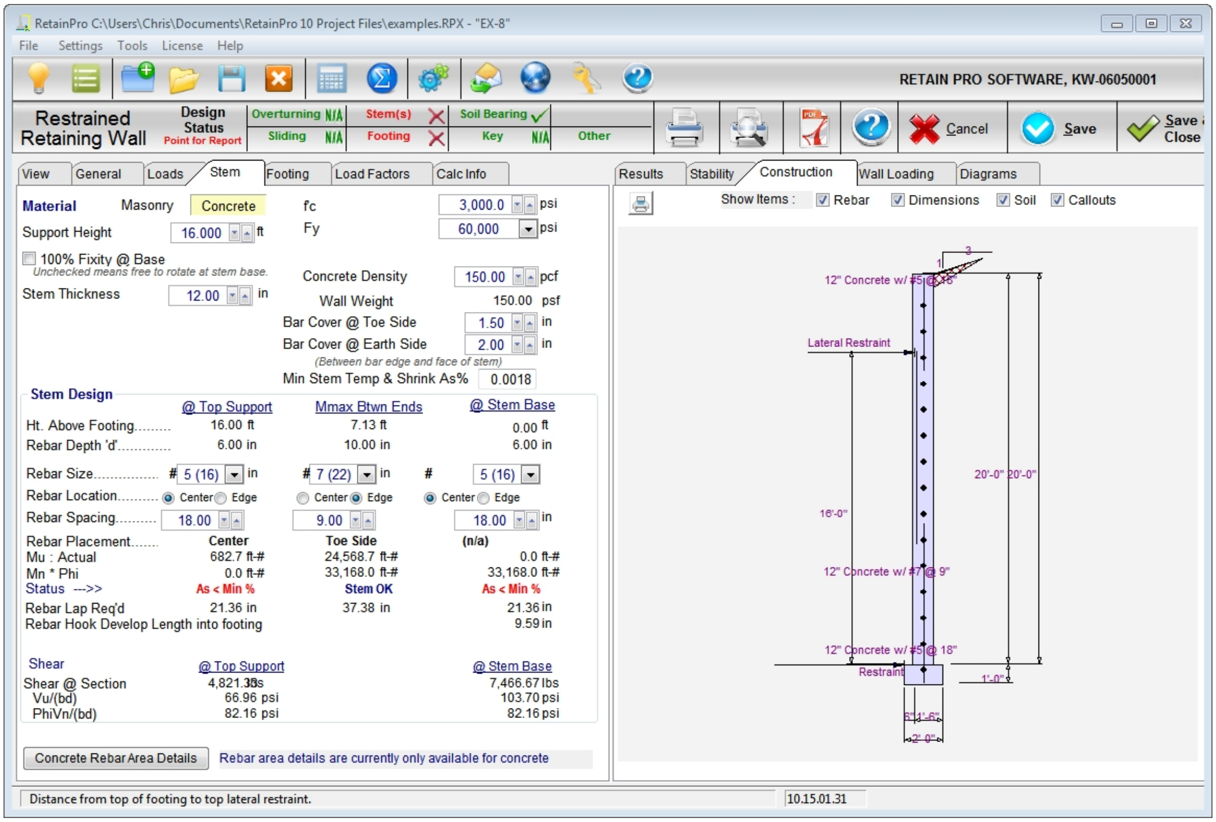
Shear @ Section: Displays total shear force at the designated height.

Actual Unit Shear: Displays the calculated shear stress at the designated height. Compare this with the allowable shear for the material you have selected.

4.3.4 Stem Tab for Restrained Retaining Wall

Stem Tab for Restrained Retaining Wall

When a Restrained Retaining Wall is defined, the Stem tab will appear as shown below:



If Restrained Stem is selected, you may have a lateral support (such as an abutting roof, slab-on-grade over backfill, or tiebacks). The lateral support should be near the top of the wall, although some extension of the wall above the support is permitted by the program. You have the option of fixing the base (as for a cantilevered wall) or assuming it pinned. Intermediate degrees of fixity are not permitted. The program will compute moments, shears, and stresses at three locations: base (negative moment if fixed; zero moment if pinned), maximum positive moment between base and lateral support, and at the point of lateral support.

Material: Select Masonry or Concrete. Only one material can be used, and must be of constant thickness.

Support Height: Use the spinners to define the height from base to the elevation of the lateral support.

100% Fixity @ Base: Clicking this box will model the stem as being fully fixed at the base (connection to the footing). If unchecked, the stem will be considered pinned to the footing (no moment fixity).

Stem Thickness: The program only permits a constant thickness throughout the height of the wall. Use the spinners to establish the stem thickness. If Masonry is chosen, the drop-down list box will offer common CMU sizes.

Design Method: (Only applies to Masonry stems) Select the design method to be used, either ASD or LRFD.

Multiply Block Weight By: (Only applies to Masonry stems) Provides a multiplier input field in case it becomes necessary to adjust the data. See Appendix C for masonry wall weights.

Solid Grout: (Only applies to Masonry stems) If this box is checked the weight of the wall will be based upon industry standard values for the weights of solid-grouted walls of lightweight, medium weight, or normal weight block based on the selection for CMU weight type. If this box is not checked, the program will calculate the weight based upon grouting of only cells containing reinforcing. This also affects equivalent solid thickness for stem shear calculations, and area for axial stress calculations (combined with moment for masonry stems).

f'm: For Masonry stem segments, enter the compressive strength of masonry in units of psi. This input is not applicable to Concrete stem segments.

f'c: For Concrete stem segments, enter the compressive strength of concrete in units of psi. This input is not applicable to Masonry stem segments.

F_s: For ASD masonry design, select the allowable steel stress, based on working stress design, which should be used for design of the masonry stem segment. The drop-down list box allows quick selection of common values. This input is not applicable to LRFD masonry design or to concrete design.

Fy: For LRFD masonry design and for concrete design, select the rebar yield stress to used for design of the indicated stem segment. The drop-down list box allows quick selection of common values. This input is not applicable to ASD masonry design.

Em = f'm *: This input collects the value by which the compressive strength of masonry is multiplied to arrive at the value of the modulus of elasticity for masonry. IBC '06 specifies E_m = 900*f'$_m$ which is the default value.

CMU Type: (Applies to Masonry stem segments only.) This input provides a drop-down list box that offers the common CMU weights.

Concrete Density: (Applies to Concrete stems only.) This input provides spinners to define the unit weight of the concrete for the stem.

Rebar Cover: This appears if a concrete stem is chosen and lets you enter desired cover on toe and earth side. The cover is used to calculate the "d" dimension when the rebar is specified to be in the "Edge" position of Concrete stems in the Stem Design category, which is explained in more detail below. When the rebar is specified to be in the "Edge" position of Masonry stems, the program uses tabular data on the geometry of various CMU sizes to calculate the "d" dimension. (Refer to the "Stem Tab for Cantilevered Retaining Wall" topic for detailed information regarding the calculated "d" dimension for Masonry stems.)

Stem Design

This allows you to design or check wall moment and shear at three locations: @ Top Support, @ M_{max} Between Ends, and @ Stem Base. If base is pinned, the entries under @ Stem Base will be zero or dimmed.

Ht. Above Footing: This displays, from left to right, the distance from the top of footing up to the lateral support, the distance from the top of footing up to the point of maximum positive moment, and it displays 0.00 ft to represent the design that is performed at the base of the stem.

Rebar Depth "d": From the thickness and center/edge condition, the program determines the "d" dimension to be used for design (using internal tables and default modifications). See Rebar Position above. For concrete stems with bars in the "Edge" position, the program automatically uses the specified clear cover and assumes a one-half inch allowance for one-half of a bar diameter when determining "d".

Rebar Size: Select from the drop-down list box.

Rebar Location: Choose Center or Edge placement.

Rebar Spacing: For Concrete stems, use the spinners to increment the rebar spacing. For Masonry stems, use the drop-down list box to select a modular spacing.

Rebar Placement: Serves as a convenient reminder to indicate which side of the wall the specified rebar is considered to be placed on.

Mu: (Only for Concrete Stems and for Masonry Stems designed according to LRFD) Displays factored moments at the indicated locations with (+) and (-) as applicable. For concrete stems and for masonry stems designed according to LRFD, the moments will be factored by the load factors specified on the Load Factors tab.

Actual Moment: (Only for Masonry Stems designed according to ASD) Displays actual moments at the indicated locations with (+) and (-) as applicable.

ϕMn: (Only for Concrete Stems and for Masonry Stems designed according to LRFD) This is the design moment strength, which will be based upon the bar sizes and spacings you established, along with wall geometry, concrete strength, etc.

Allowable Moment: (Only for Masonry Stems designed according to ASD) This is the allowable moment capacity based upon the bar sizes and spacings you established, along with wall geometry, concrete strength, etc.

Status: This indicates whether the stem design is OK at the specified height. If there is a problem, this will display a descriptive message such as "Mu > Phi * Mn" or "As < min" or "As > max" or "Ftg. Rebar Embed!".

Rebar Lap Req'd: For masonry, the lap required is 48 bar diameters for F_s = 32,000 psi and 40 diameters for F_s = 20,000 psi. For concrete, a Class B splice is assumed, which multiplies the development length by 1.3 (See ACI 12.15.2), and excludes reduction for stress level. Note: The program does not compute or display bar cut-off points, which must be done manually, or extend positive reinforcing so it is acceptable.

Rebar Hook Development Length into Footing: This is the hooked development length that is required for the bar size specified at the stem base. It is based on the assumption that the bar is hooked into the footing with a 90° bend and minimum 12 d_b bar extension. The calculated values is also based on the assumption that the side cover (normal to the plane of the hook) is not less than 2.5 inches and that the cover on the extension beyond the hook is not less than 2 inches. These latter assumptions facilitate the application of a factor of 0.7 to the calculated value of l_{dh}.

Shear at Section: This is the total shear force at the indicated height (factored for concrete or masonry designed according to LRFD).

Factored Shear Stress: (or Applied Shear Stress for Masonry Stems designed according to ASD) Shear stress at designated height computed by Shear at Section / (12 ∗ "d") (factored for concrete or masonry designed according to LRFD).

Design Shear Strength: (or Allowable Shear Stress for Masonry Stems designed according to ASD) For masonry designed by ASD according to TMS 402/ACI 530, the allowable shear stress varies between 3*sqrt(f'm) and 2*sqrt(f'm) as a function of M/(Vd). No contribution of shear strength is assumed from reinforcing steel in a retaining wall.

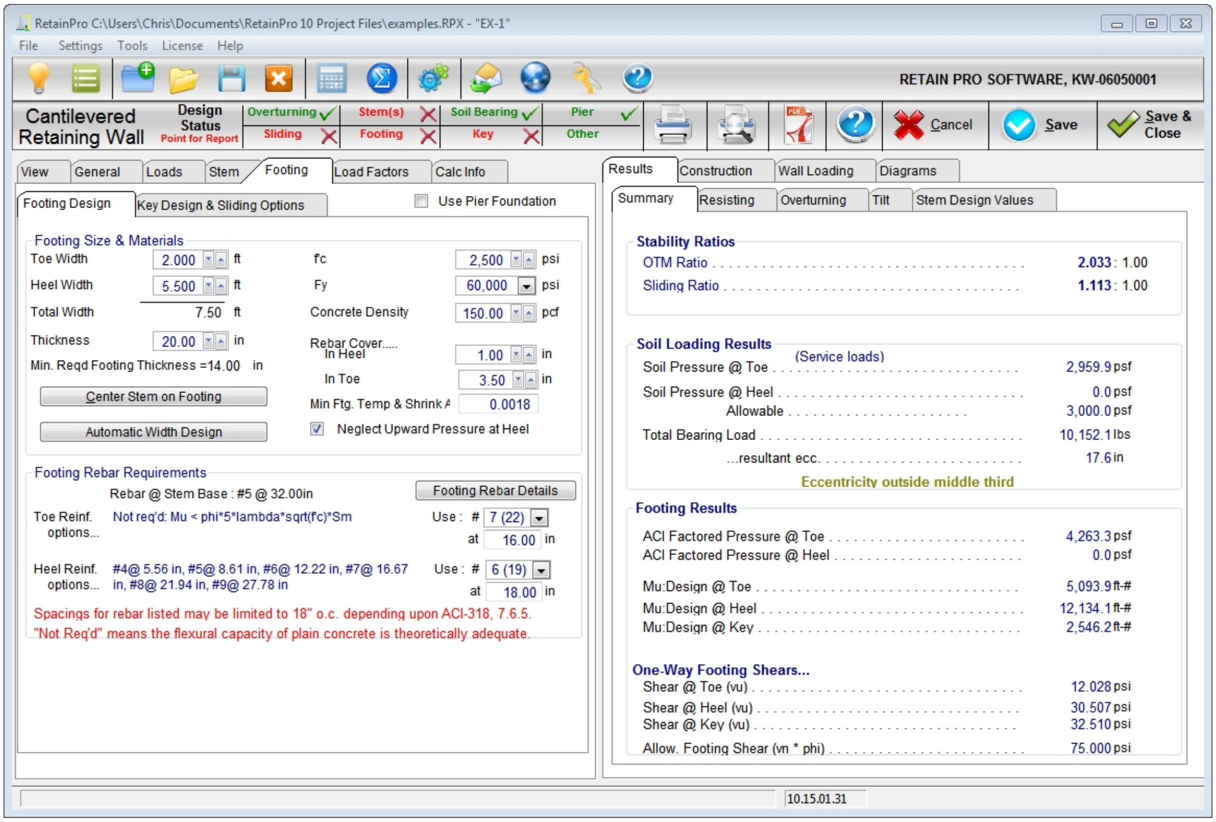
For masonry designed by LRFD according to TMS 402/ACI 530, the nominal shear strength varies between 6*Anv*sqrt(f'm) and 4*Anv*sqrt(f'm) as a function of M/(Vd). Again, no contribution of shear strength is assumed from reinforcing steel in a retaining wall.

For concrete, the nominal shear strength is 2*λ*sqrt(f'c), per ACI 318.

4.4 Footing Tab

Footing Tab

The Footing tab collects the data required to define the footing geometry and reinforcing, and the key geometry and reinforcing if one is present. This is also where certain design decisions can be made regarding how the program handles the sliding calculations.



4.4.1 Footing Design Sub-tab

Footing Design Sub-tab

Footing Size & Materials

Toe Width: This is the width of the Toe of the footing, and is measured from the front edge of the footing to the front face of the stem. Can be set to 0.00 for a property line condition. All overturning and resisting moments are taken about the bottom-front edge of the toe.

Heel Width: Distance from front face of stem to back of heel projection. If a dimension is entered that is less than the stem width at the base, the program will automatically reset the heel dimension to at least the stem width. For a property line at the rear face of the stem, set this dimension to be equal to the stem width.

Total Footing Width: The calculated width of the footing, Toe Width + Heel Width.

Thickness: Total footing thickness, NOT including the key depth (if used). For bending and shear design of the footing, the rebar depth "d" is taken as Footing Depth - Rebar Cover - ½" (the additional 1/2" is to account for the rebar radius). If footing thickness is inadequate for shear capacity a red warning indicator will appear.

The footing thickness must be greater than the hooked rebar embedment length required for the bottom stem reinforcing + rebar cover. The program adds the calculated hooked bar embedment from the Stem screen and adds it to the rebar cover you have chosen for the bottom of the footing (usually 3"). If the specified thickness is inadequate, increase the thickness, or change the stem dowels.

Center Stem on Footing: Clicking this bar will adjust the toe and heel widths you have entered so the stem is centered on the footing but the overall footing width remains the same.

Automatic Width Design: Clicking this button will cause the program to iterate footing widths until the soil pressure and footing strength are acceptable. ***(Note: This function does not optimize for overturning stability or sliding stability, so those will need to be checked after using this option.)*** You can select either a fixed toe or heel distance, or balance the toe and heel dimensions. You can also select whether the resultant must be within the middle third of the footing. After clicking “Design,” the widths required will be displayed. Automatic footing design is not available for Restrained Walls, Gravity Walls, or Segmental Walls.

f'c: Enter concrete compressive stress for footing.

F_y: Allowable rebar yield stress to be used for design of footing bending reinforcement.

Rebar Cover in Heel/Toe: Distance from the face of concrete to edge of rebar. The program will add 1/2" to this value and subtract the result from the footing thickness to determine the bending "d" distance.

Minimum Temperature & Shrinkage A_s Percentage: Enter the minimum steel percentage to address temperature and shrinkage requirements in the footing (commonly 0.0018 Ag for F_y= 60,000 psi). If the % steel required by stress analysis is less than 200/F_y, the minimum of (200/F_y -or- 1.333 * bending percentage required) is calculated and compared with the Minimum Temperature & Shrinkage A_s % entered here, and the greater of the two is used to calculate rebar spacing requirements.

Neglect Upward Pressure at Heel: For heel calculations you may choose to neglect the upward soil pressure, typically resulting in greater heel moment. If this box is checked the M_u for upward loads will be zero.

Footing Rebar Requirements

Rebar at Stem Base: This is a reminder of the size and spacing of the reinforcing used at the bottom of the stem, to make it easier to select toe reinforcing to match (toe reinforcing is usually the bottom stem dowel bars bent toward the toe).

Toe Reinforcing Options: This list provides options for reinforcing sizes and spacing for the toe bars (located in the bottom of the footing). Typically the toe bars are extensions of the stem dowels, which are bent out toward the toe. Therefore, you will probably just want to verify that the stem dowel bar size and spacing would also be adequate for use in the toe.

NOTE: If “No reinf’ req’d” message appears, it means the flexural capacity of the footing (modulus of rupture times the section modulus, with 2” deducted from the thickness for crack allowance per code) is adequate to resist the applied moment. However, the designer in some cases may consider it prudent to add reinforcing regardless of the theoretical flexural capacity. For plain concrete per ACI 22.5.1, $F_r = \Phi 5\lambda(f'_c)^{1/2}$.

Heel Reinforcing Options: This list provides options for acceptable sizes and spacing for heel bars (located in the top of the footing). It is desirable to select a spacing that is modular with the stem dowel bars for ease of construction. Note: The program does not calculate the heel bar development length inward from the back face of the stem (where the moment is maximum). You can refer to Appendix B for development lengths in concrete, which can be adjusted for the stress level in the heel bars. When detailing footing reinforcing it is important to consider and specify development lengths for both toe and heel bars.

NOTE: If “No reinf’ req’d” message appears, it means the flexural capacity of the footing (modulus of rupture times the section modulus, with 2” deducted from the thickness for crack allowance per code) is adequate to resist the applied moment. However, the designer in some cases may consider it prudent to add reinforcing regardless of the theoretical flexural capacity.

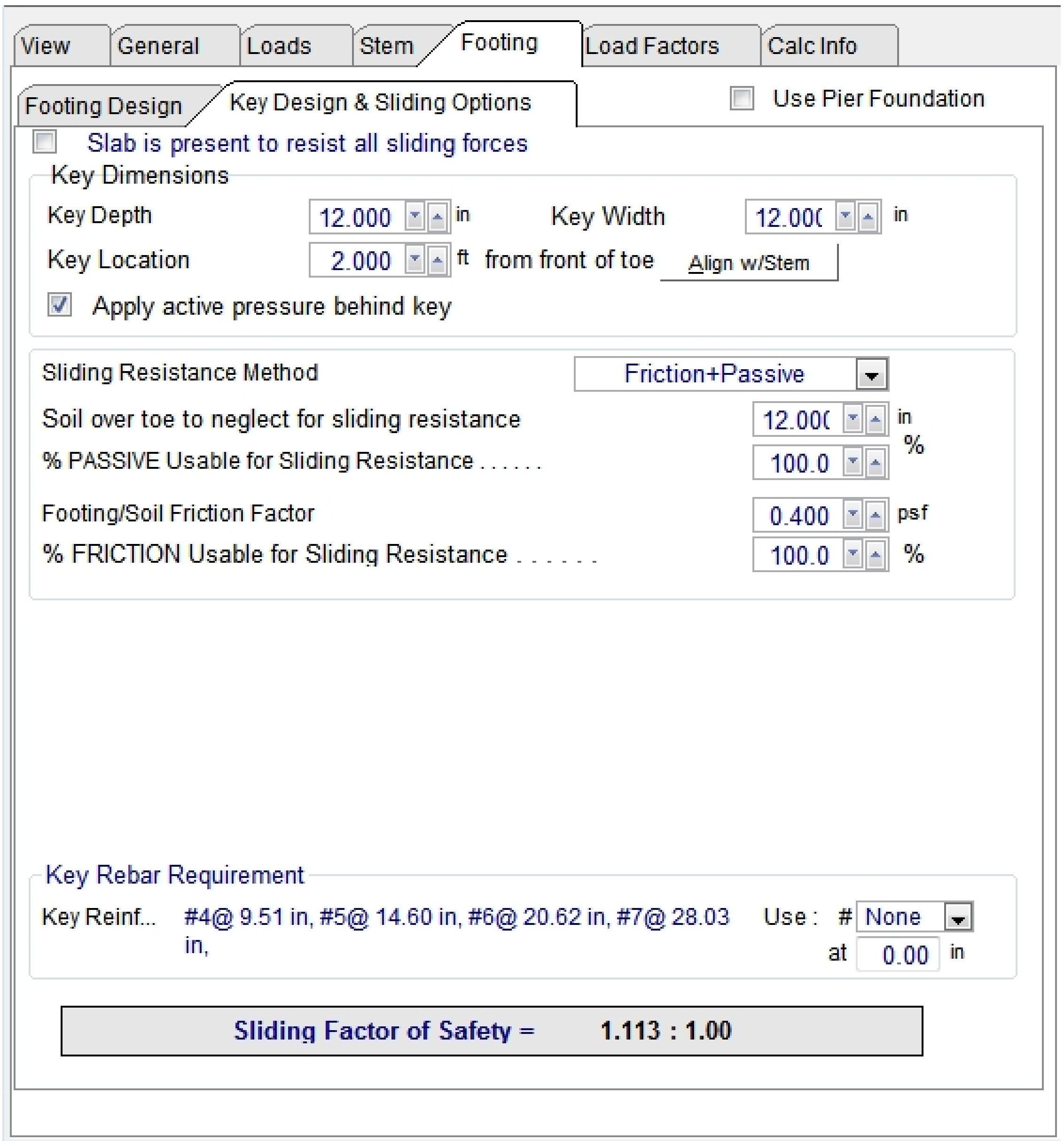
Rebar Selections: Use these three size and spacing entries to select your toe, heel, and if applicable, key reinforcing. The "Max

@" message tells you the maximum spacing allowed for the bar selected.

4.4.2 Key Design & Sliding Options

Key Design & Sliding Options

This screen is used to indicate whether a key is to be used, and if so, specify its dimensions. This screen also collects information about the design intent for the sliding check, and presents a summary of the sliding forces.



Slab is present to resist all sliding forces: Provides a way to communicate to the program that sliding is not a design consideration, because in the designer's judgment, sliding is completely precluded, such as by a slab on grade on the toe side of the wall that prevents sliding altogether. If this option is selected, the lateral sliding force is displayed for checking the resistance offered by the slab, and the slab is assumed to be at the top of the footing, but not higher.

Key Dimensions

Key Depth: Depth of the key below the bottom of footing. The bottom of the key is used as the lower horizontal plane for determining the size of the passive pressure block from the soil in front of the footing. Adjust this depth so the sliding safety factor is acceptable, but not less than 1.5.

Key Width: Width of the key, measured along the same direction as the footing width. This is usually 12"-14", but generally not less than one-half the key depth so flexural stresses in the key are usually minimal.

Key Location: Enter the distance from the front edge of the toe to the front of the key. Do not enter a distance greater than the footing width minus key width.

Align with Stem: Click this button to align the front edge of key with the front of the stem. If the key width is then set to a value that is reasonably close to the stem width, the stem bars may be able to be extended down into the key to facilitate rebar development.

Apply active pressure behind key: When this option is selected, the program will consider the driving force to extend all the way to the bottom of the key. If this option is NOT selected (such as to check the stability of a design that was performed based on a code prior to IBC 2009 and CBC 2010) then the driving force will not extend below the bottom of the footing.

Sliding Resistance Method: Enter whether sliding resistance will be by friction and passive pressure or by cohesion and passive pressure.

Soil Over Toe to Neglect for Sliding Resistance: Since the soil over the toe of the footing may be loose and uncompacted, it may have little or no passive resistance. This entry gives the option to neglect some portion of the Height of Soil Over Toe entered in the General tab. You can neglect the soil over toe plus the footing thickness, if desired.

% Passive Usable for Sliding Resistance: Enter a value from zero to 100% to indicate the percentage of the calculated passive pressure that will be used as resistance in the sliding calculation. This may be a stated restriction in the geotechnical report.

Footing/Soil Friction Factor: Enter the friction factor here. It usually varies from 0.25 to 0.45, and is generally provided by the geotechnical engineer.

% Friction Usable for Sliding Resistance: Enter a value from zero to 100% to indicate the percentage of the calculated friction force that will be used as resistance in the sliding calculation. This may be a stated restriction in the geotechnical report.

Summary of Sliding Forces

Lateral Force @ Base of Footing: This is the total lateral force against the stem and footing which causes the wall to slide and which must be resisted.

Less Passive Pressure Force: This uses the allowable passive pressure in pcf and the available depth ("footing thickness" plus "soil above toe" less "height to neglect") multiplied by the "percent usable" you specified to compute the total passive resistance. Weight due to toe surcharge, if applicable, will also be incorporated into the calculation of the passive force. If a key is used, the available passive pressure depth will be to the bottom of the key.

Less Friction Force: This is the total vertical reaction multiplied by the friction factor, and then multiplied by the "percent usable" you specified.

Added Resisting Force Required: If this value is indicated as 0.0 lbs., then there is no requirement for additional resisting force in order to achieve a static balance of forces, but it does not necessarily mean that there is an adequate factor of safety against sliding. Watch the Sliding Ratio on the Results tab, Summary sub-tab for an adequate value (usually 1.5). Consider adding a key or modifying footing geometry if required.

Added Resisting Force Required for 1.5:1 Factor of Safety: This is the additional resisting force that would be required in order to achieve a 1.5 safety factor. If this value is indicated as 0.0 lbs., then the Siding Ratio is already 1.5 or greater.

Key Rebar Requirement

Key Reinforcing: This area indicates the permissible spacing values for a variety of logical rebar sizes, and allows the user to specify the size and spacing of the rebar in the key.

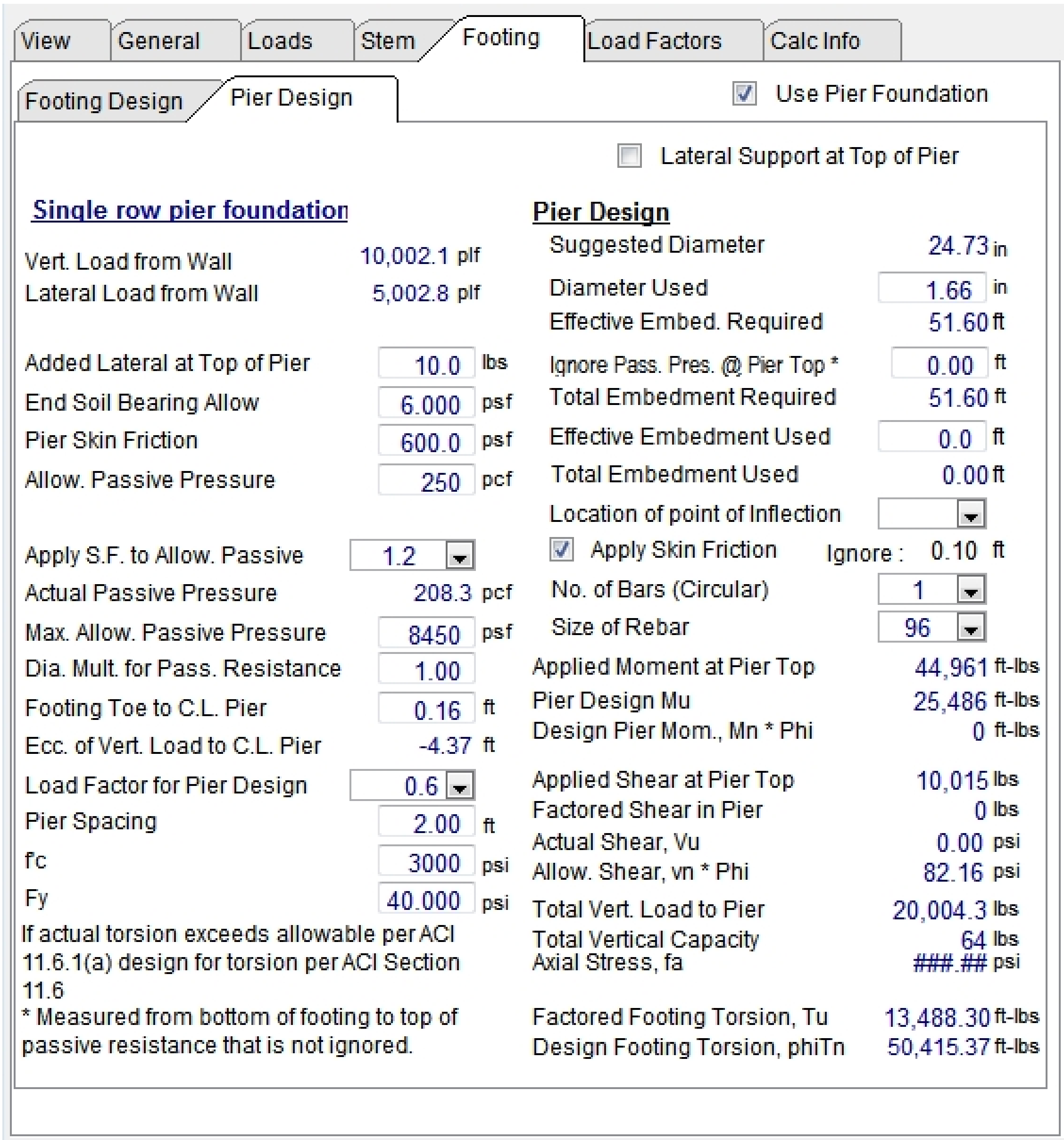
Sliding Factor of Safety: This reports the ratio of passive and friction resistance to the total lateral force. This should be at least 1.5, or 1.1 if seismic is activated.

NOTE: If lateral restraint is provided by an abutting floor slab (by checking the "Slab is present..." box), the sliding factor of safety will not be displayed, but the “Lateral Force @ Base of Footing” will be displayed for checking restraint adequacy of the slab.

4.4.3 Pier Design

Pier Design

Checking the Use Pier Foundation checkbox (on the sub-tabs under the Footing tab) will replace the Key Design & Sliding Options sub-tab with the Pier Design sub-tab as shown below:



This allows you to use drilled cast-in-place concrete piers spaced in a single row along the length of the wall. The default is without lateral support at the footing level. If lateral support is available, such as an abutting slab at the footing level, check the box labeled "Lateral support at Top of Pier". The Key Dimensions & Sliding tab is not applicable when piers are used so the Key Dimensions & Sliding

Options tab is not displayed when the Use Pier Foundation checkbox is checked. However, the Footing Design tab does remain active, so you can adjust the footing dimensions as necessary for the piers, and adjust as needed for torsion resistance (see below).

Lateral Support at Top of Pier: Provides a way to specify that there is lateral restraint at or near the top of the pier. If this option is checked, the program will offer a related item named "Assumed Fixity Below Embed"

Vert. Load from Wall, plf: Displays the total vertical load imposed upon the piers from the wall above, including the footing weight. It matches the total vertical load from the Resisting Moment summary.

Lateral Load from Wall, plf: Displays the net sliding force and matches the total force shown on the Overturning Moments summary for the wall.

Added Lateral at Top of Pier, lbs: The geotechnical engineer may recommend an added lateral force at or near the top of the pier (sometimes termed “creep”). This may be a triangular force but for simplicity it is assumed to act at the top of the pier.

End Soil Bearing Allow, psf: Allowable end bearing pressure at bottom of pier.

Pier Skin Friction, psf: If applicable, enter the allowable skin friction on the pier for added vertical load capacity. This may require conversion from a friction angle.

Allow. Passive Pressure, pcf: This is used to define the variation in allowable passive pressure with depth.

Apply Safety Factor to Allowable Passive Pressure: Allows the user to use a drop-down list box to select a safety factor that will be applied to the calculated passive pressure

Actual Passive Pressure, pcf: Reports the value of Allowable Passive Pressure in pcf divided by the safety factor selected above.

Max. Allow. Passive Pressure, psf: Specifies the upper limit on the allowable passive pressure. The allowable passive pressure will increase with depth until it reaches this value, at which point the allowable passive pressure will remain constant at this value.

Diameter Multiplier for Pass. Resistance: The geotechnical engineer may permit a multiplier to the diameter for greater effective passive resistance. The default is 1.0.

Diameter Required, in: Diameter required based upon applied Vertical Load and the allowable end soil bearing pressure.

Diameter Used, in: If skin friction is used (activated by checkbox below) the diameter can be adjusted provided Total Bearing Capacity exceeds Total Vert. Load to Pier.

Effective Embedment Required, ft: This uses the “pole embedment” equations per IBC ’06 Section 1805.7.2 or IBC '09 Section 1807.3 or IBC '12 Section 1807.3 to determine the required pier embedment depth based upon the passive pressure entered and the applied moment to pier. The embedment depth will vary depending upon whether the checkbox for lateral support at top is checked.

Ignore Passive Pressure from Pier Top, ft: Since the soil near the top of a drilled pier may be disturbed and uncompacted, it may have little or no passive resistance. This entry gives the option to neglect the passive pressure over the specified height at the top of the drilled pier.

Total Embedment Required, ft: Displays the sum of "Effective Embedment Required" plus "Ignore Passive Pressure from Pier Top".

Effective Embedment Used, ft: Input a depth of embedment considered to be effective below the section where passive pressure is being ignored.

Total Embedment Used, ft: Displays the sum of "Effective Embedment Used" plus "Ignore Passive Pressure from Pier Top".

Location of point of inflection: Use the drop-down list box to select the ratio of depth-to-inflection to effective embedment depth. Tests suggest 1/6 is reasonable; 1/3 is conservative. This will be used to calculate the maximum moment applied to pier. The resulting length will be measured below the zone where passive pressure is ignored (if any).

Apply Skin Friction (with option to ignore some length of skin friction): Check this if skin friction is to be used to increase vertical capacity of pier. If selected, there is an entry for depth to be ignored for skin friction.

No. of Bars (circular): Select the number of bars. They are assumed to be in a circular pattern.

Size of Rebar: Select size of bars to use in the circular pattern.

Applied Moment at Pier Top, ft-lbs: Displays the wall overturning moment multiplied by the pier spacing.

Pier Design Mu, ft-lbs: This is the total factored design moment applied to the pier.

Allow. Pier Mom., phi Mn, ft-lbs: Displays the design moment capacity of the pier using the strength values input and a phi factor of 0.90. This uses the Whitney Approximation method which is slightly conservative.

Applied Shear at Pier Top, lbs: Displays the Lateral Load from Wall multiplied by the pier spacing.

Shear in Pier, lbs: Displays the total factored design shear applied to the pier. It includes lateral load from the wall, and additional shear due to the pier reacting out the applied moment.

Actual Shear, V_u, psi: Displays factored shear stress determined using Whitney Equivalent Rectangular Section.
Width = b = 0.8 * Diam.
Area of Whitney Equivalent Rectangular Section = Area of circular pier
H = Area / b
d = 0.67 * H
Aeff = b * d

Allow. Shear, phi V_n, psi: Displays design shear strength using a phi value of 0.75: phi $v_n = 0.75*2*(f_c)^{1/2}$

Total Vert. Load to Pier, lbs: Displays the Vertical Load from Wall multiplied by the pier spacing.

Total Vertical Capacity, lbs: This combines both end bearing capacity and skin friction, as applicable.

Axial Stress, fa, psi: This is the total vertical load / pier area. This is for reference only since it is not considered a critical design consideration.

Footing Torsion, Tu, ft-lbs: Displays factored torsional force in footing, which is calculated as moment from wall multiplied by one-half pier spacing.

Footing Torsion Allow., phi Tn, ft-lbs: Displays torsional design strength of the footing based on ACI 318-05 Section 11.6.1 or ACI 318-08 Section 11.5.1 or ACI 318-11 Section 11.5.1.

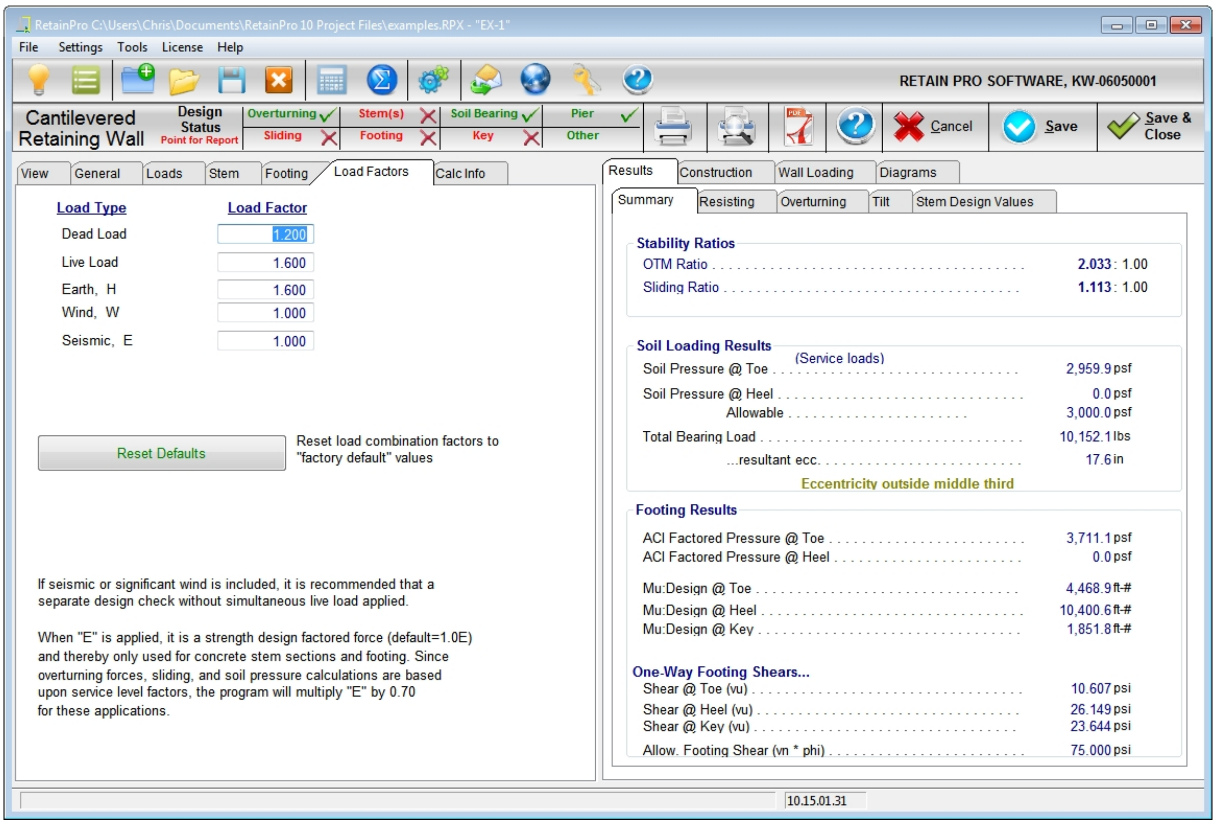
DESIGN STATUS messages: If “Pier Problem” is displayed, vertical load capacity or moment capacity is exceeded, or embedment depth is insufficient.

For more information on pier foundation design see *Basics of Retaining Wall Design*, 9th Edition

4.5 Load Factors

Load Factors

This tab allows the code-specified load factors to be reviewed and edited if necessary.



Load Type / Load Factors

For each type of load (DL, LL, etc) the default factor will be displayed. These values can be edited for the current design. If desired, the edit values can be made the default for future designs by clicking the button labeled "Set These Factors As Defaults". ***Remember to review these factors for each new design since they are editable.***

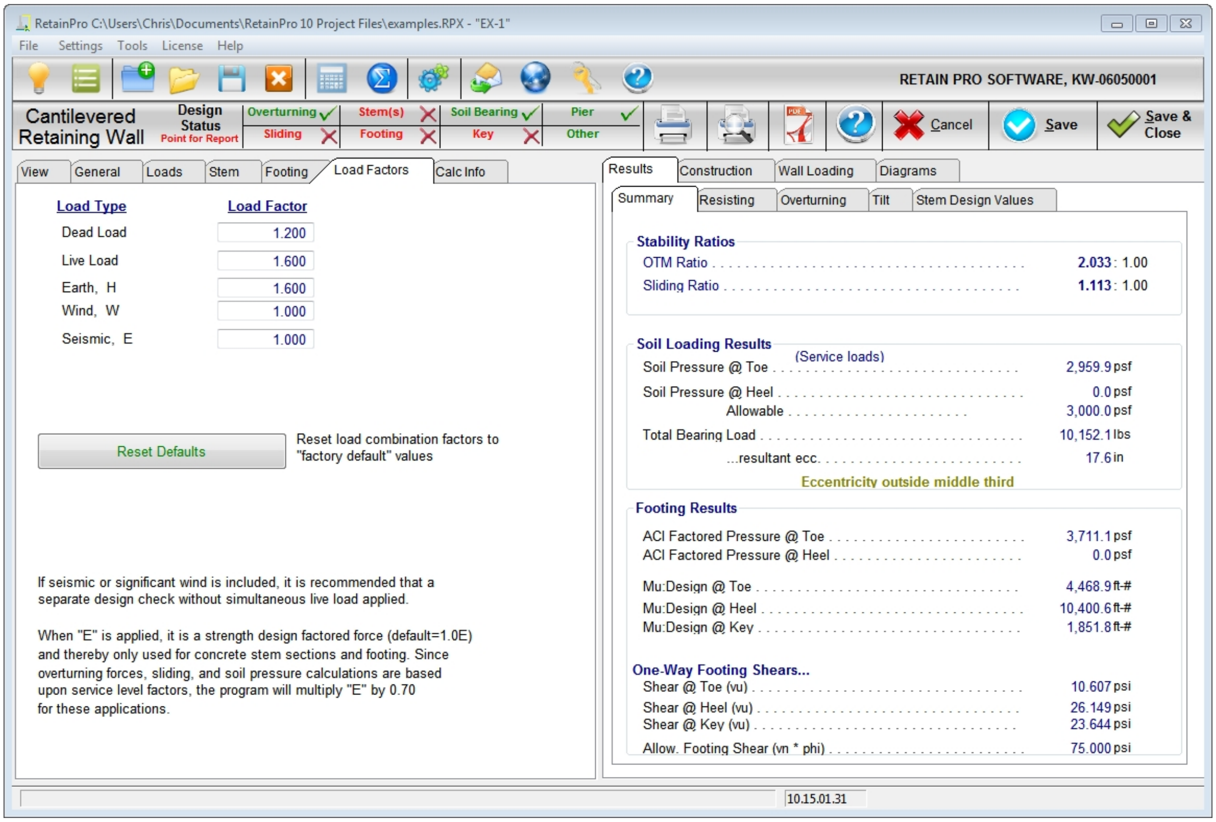
The factors shown on this tab apply to Strength Design (concrete stem sections and footing, and masonry design when LRFD is selected). For Allowable Strength Design for masonry, factors are generally set to 1.0 except that the earthquake factor (E) is 0.7, and for IBC 2012/CBC 2013, the wind load factor (W) is set to 0.6 to convert strength-level loads to service-level loads.

4.6 Results Tabs

4.6.1 Summary

Summary

This screen summarizes the footing/soil bearing results obtained from previous screens, including a message whether the resultant is within or outside the middle third of the footing. ***This is not an input screen. It's strictly for your review***.



Stability Ratios: These are displayed for both overturning and sliding.

Soil Loading Results

Soil Pressure @ Toe and Heel: This is the resulting soil pressure for both the toe and heel based on service loads. If the eccentricity is outside the middle third, the heel pressure will show 0.00, and the program will calculate the toe pressure assuming no tension at the heel.

Allowable Soil Pressure: This is for reference as entered on the General tab.

Total Bearing Load: This is the sum of all vertical forces.

Resultant Eccentricity: Distance from center of footing to the resultant of the soil pressure distribution.

Eccentricity Within/Outside Middle Third: If the eccentricity is greater than one-sixth the footing width, the resultant is outside the middle third. (If outside the middle third, the program computes the toe soil pressure assuming no tension at the heel.)

Footing Results

ACI Factored Soil Pressure @ Toe and Heel: ACI load factors are applied to all loads to determine total vertical load for soil pressure used in calculating footing moments and shears. This load is then applied at the same eccentricity calculated for service load soil pressures to yield the factored soil pressures for footing design using LRFD design principles.

Note that since factored vertical loads are applied at the non-factored resultant eccentricity, a true 1.6 load factor applied to lateral earth pressure is not used for footing design. ACI load factors are intended to give conservative results for design. Calculation of a factored load eccentricity would give soil pressure diagrams that would not always represent the actual soil pressure distribution under the footing, and yield unreasonable results. Factored lateral earth pressure, however, is always used for concrete stem design.

M_u Design @ Toe/Heel: These are the factored moments at face of stem for toe and heel moments. Since neither can be greater than the stem base moment (factored if concrete stem), the latter may govern. These moments will be reduced if you choose to neglect the upward soil pressure on the Footing tab. A message will indicate which controls.

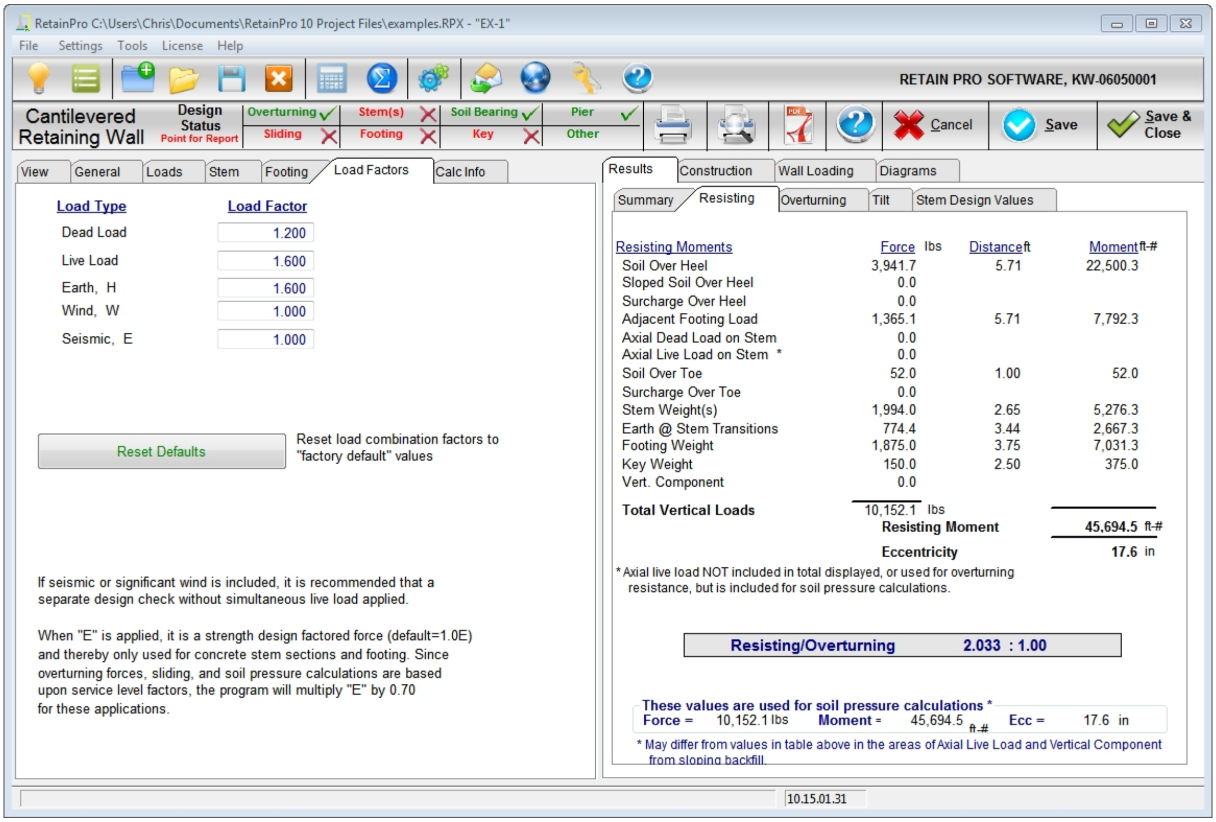
Shear @ Toe and Heel: These items report the factored shear stress from the one-way action in the footing. The toe shear stress is calculated at a distance "d" (footing thickness - rebar cover) from the face of the bottom stem segment. (If "d" is greater than the projecting toe length, then the one-way toe shear is reported as zero.) The heel shear stress is calculated at the face of the stem.

Allowable Footing Shear: The design shear strength calculated as ($0.75 * 2 * \lambda * f'c^{1/2}$).

4.6.2 Resisting Moments

Resisting Moments

This screen presents in tabular form each component contributing to resisting moment, giving weights and moment arms from the front edge of the toe to the centroid of the force.



Resisting/Overturning ratio is displayed.

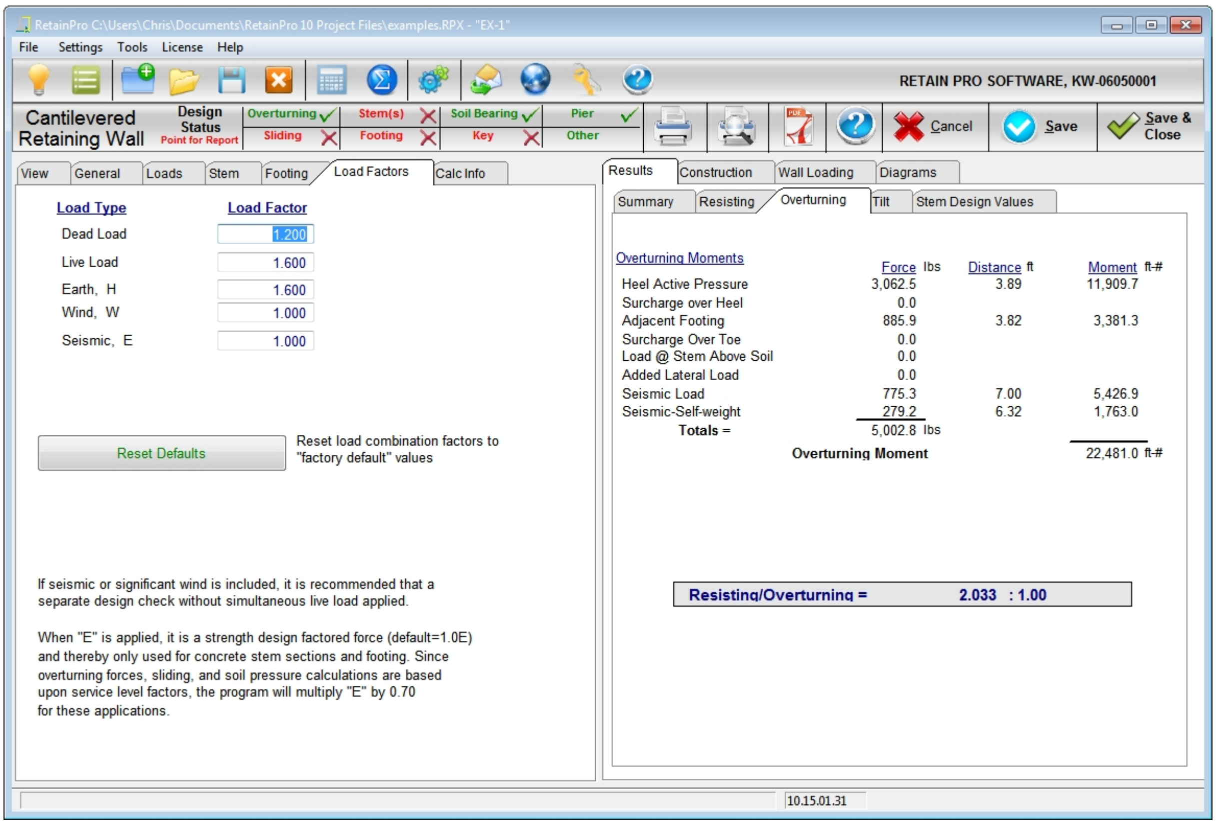
The force and moment displayed at the bottom accounts for deduction of effect of vertical component, if box on the General tab has been checked.

For calculating the vertical component, if checked on the General tab, and if the EFP method was chosen, the program will back-solve using the Rankine formula to obtain an equivalent internal friction angle.

4.6.3 Overturning Moments

Overturning Moments

This screen presents in tabular form each component acting horizontally to overturn the wall/footing system. The centroid of each force is multiplied by its distance up from the bottom of the footing. The Heel Active Pressure includes the effect of surcharges and water table, if applicable, and its Distance is to the centroid of the total lateral force.

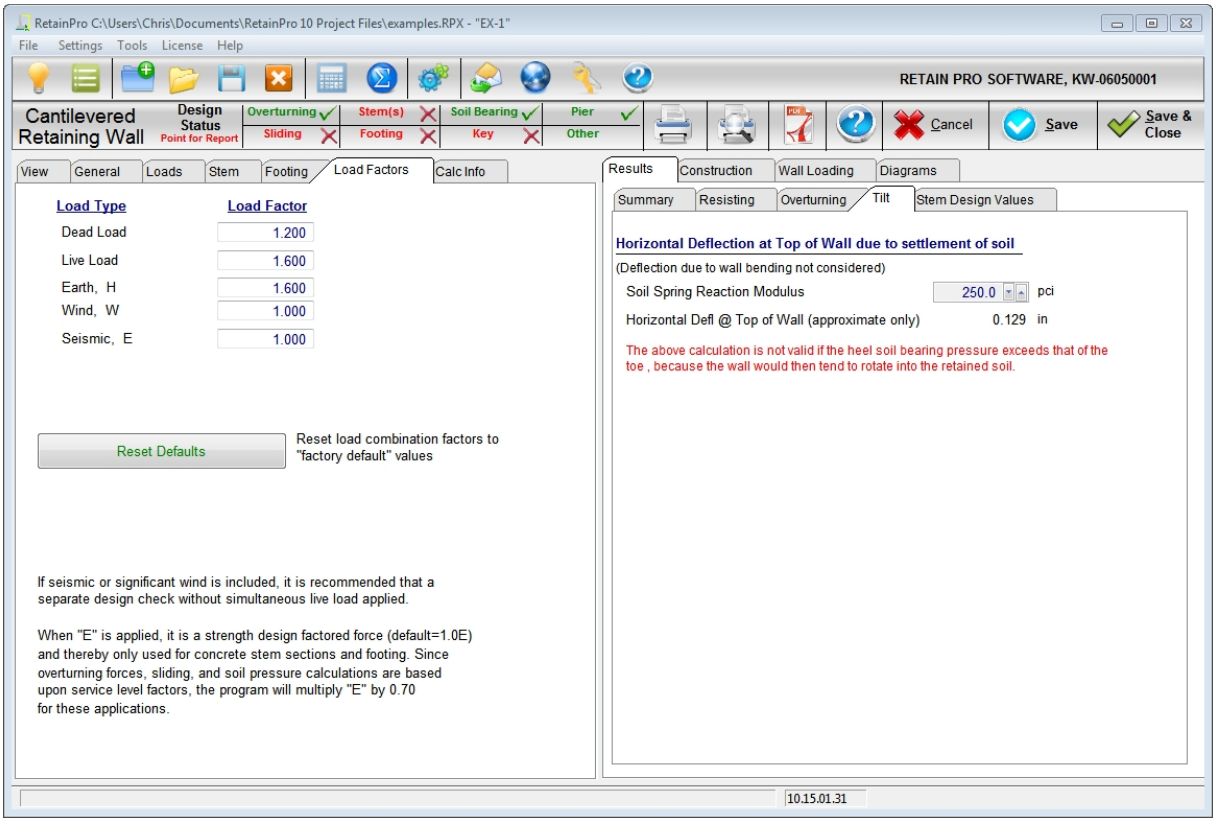


The total overturning moment is displayed along with the Resisting/Overturning ratio.

4.6.4 Wall Tilt

Wall Tilt

This computes the horizontal displacement at the top of a wall caused by rotation due to compression of the soil under the toe.



You must enter the modulus of subgrade reaction. The program divides the soil bearing stress in psi by the soil modulus (psi/inch) to quantify the displacement at the footing. Then, assuming the wall and footing are rigid, the program determines the horizontal displacement at the top of the wall based on the amount of rotation experienced at the footing.

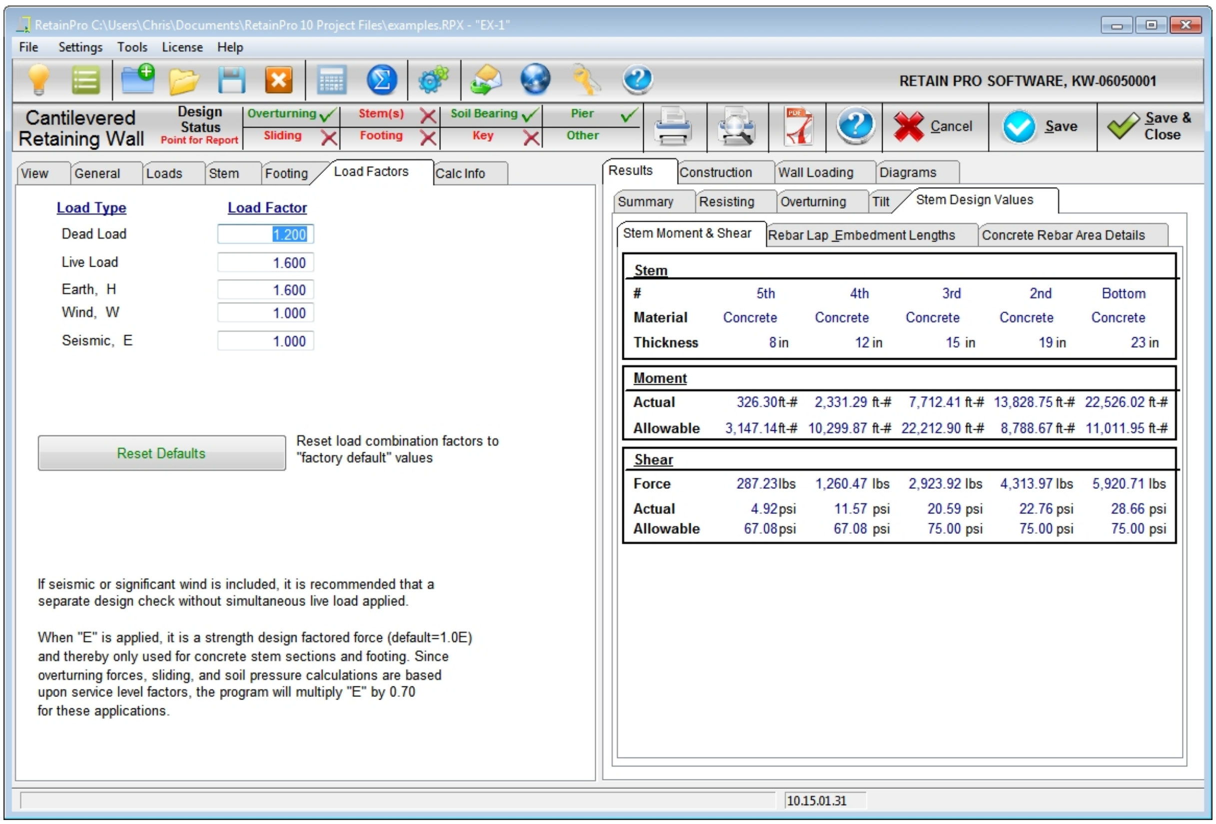
Note: This is approximate due to variation in soil pressure under the footing, and does not include deflection of the stem due to lateral earth pressures. (The latter is usually less than the "tilt" deflection, and if desired, must be done by hand calculation, requiring investigation of cracked and uncracked moments of inertia.)

To mobilize the active pressure in retained earth, it is often considered that the deflection at top must be greater than or equal to 0.005 x H_{total}.

4.6.5 Stem Design Values

Stem Design Values

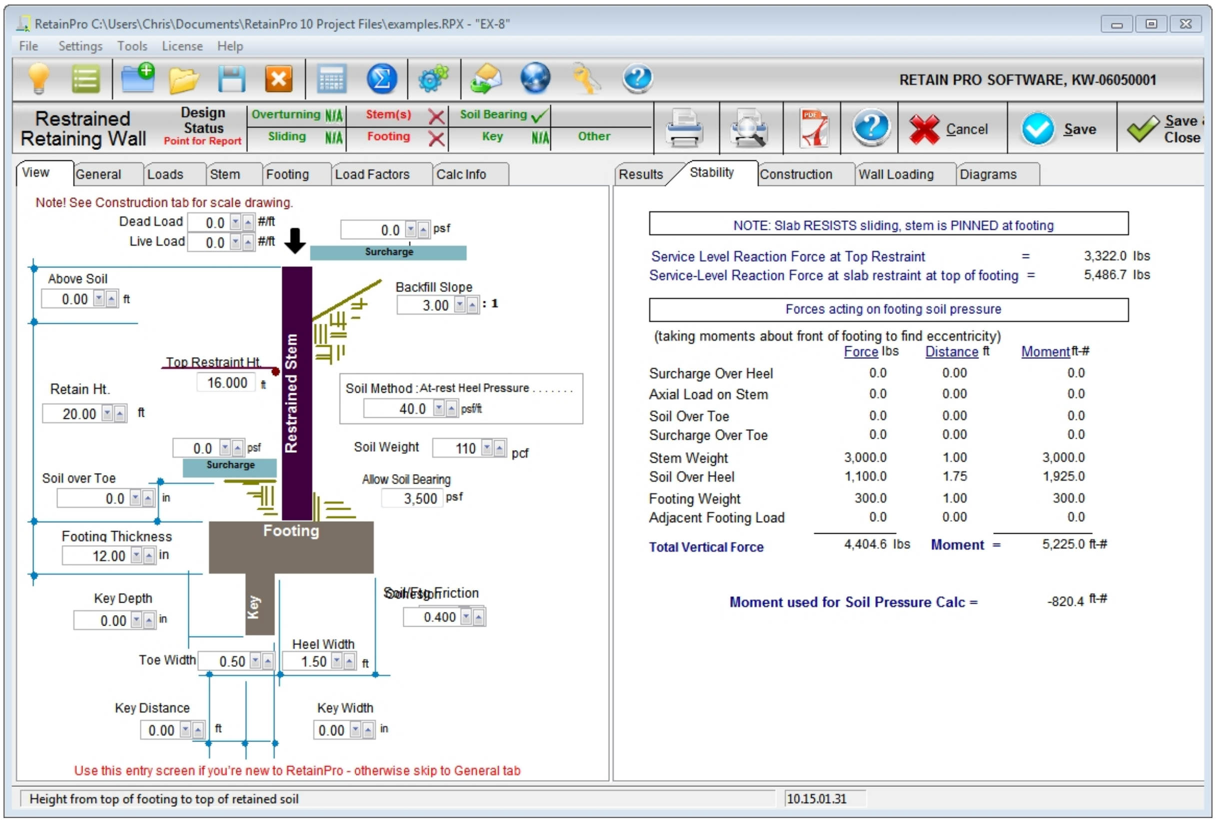
This tab was introduced in order to make it possible to view stem design values while the input focus is on tabs other than the Stem tab. This makes it easier to view the effects on stem moment and shear while changing other parameters such as retained height, backfill density, etc. It also includes subtabs to view the Rebar Lap & Embedment Length table and the Concrete Rebar Area Details table.



4.7 Stability Tab (Restrained Walls only)

Stability (Restrained Walls)

For Restrained Walls the Stability sub-tab will appear, summarizing the conditions regarding base fixity and base lateral restraint.



A banner displays whether a slab is present to resist base sliding (box checked on Footing > Key Design tab) and whether fixed or pinned at base, as previously selected on the Stem tab.

The reaction at the top restraint is displayed.

The Sliding forces are displayed.

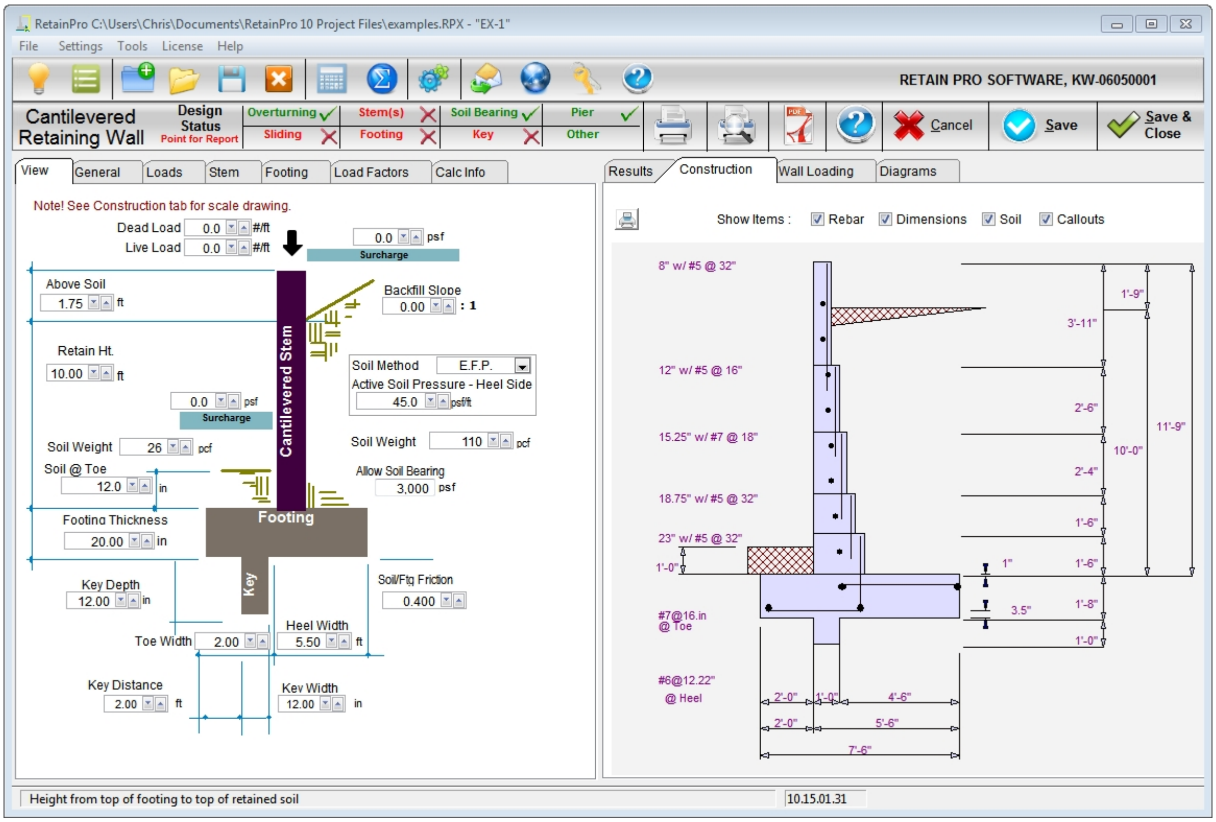
For analyzing the stem, if it is assumed “pinned” at the bottom (option is located on the Stem tab), and a slab is not present to resist sliding, then the theoretical overturning of the footing due to the reaction at the base of the stem, is the horizontal reaction at the bottom of the stem times the thickness of the footing.

If slab restraint is provided, the moment applied to the footing is the total vertical load times its eccentricity from the center of the footing. This moment is displayed (on the Stability tab) and is used to compute soil pressure.

4.8 Construction Tab

Construction

This graphics screen displays a construction drawing showing the pertinent construction data for the wall as you have entered it. It can be printed, copied to the Windows clipboard, or a DXF file can be generated for importing to your CAD software. This graphic is intended as a check of your input and is not editable.



To print, use Print button at top left. Layers of information can be turned on and off by checkboxes across the top of the drawing view.

This drawing will not depict the wall in a graphically correct way until sufficient data has been entered. Only a default graphic will appear initially.

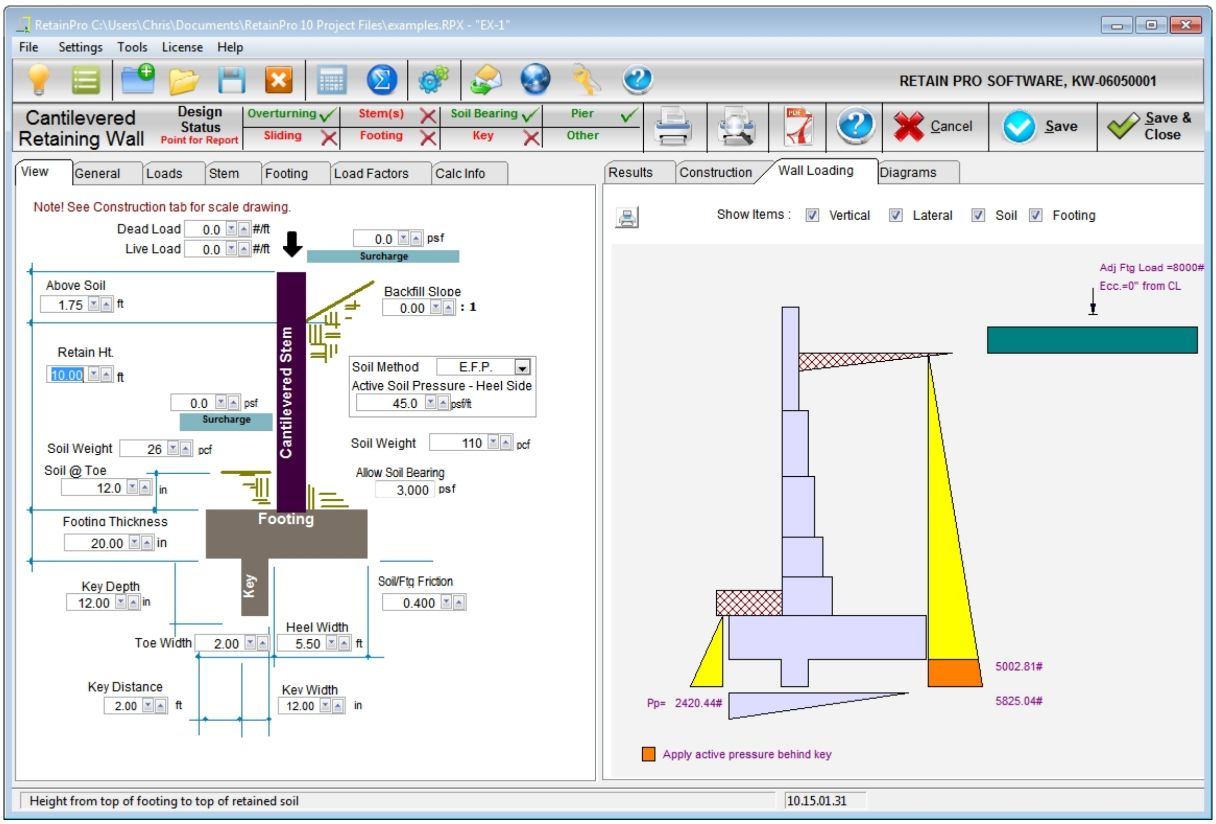
4.9 Wall Loading Tab

Wall Loading Diagram

This diagram displays the active or at-rest pressure distribution, the passive pressure distribution, any applied loads that have been defined, and the maximum soil pressure distribution.

Loads are color-coded and may be turned on and off by using the checkboxes across the top of the diagram.

To print, use button at upper left.



Note that if seismic or adjacent footing loads are used, the Wall Loading diagram does not graphically depict these loads, but they are included in the reaction shown at the bottom of the diagram.

This feature not available for segmental walls

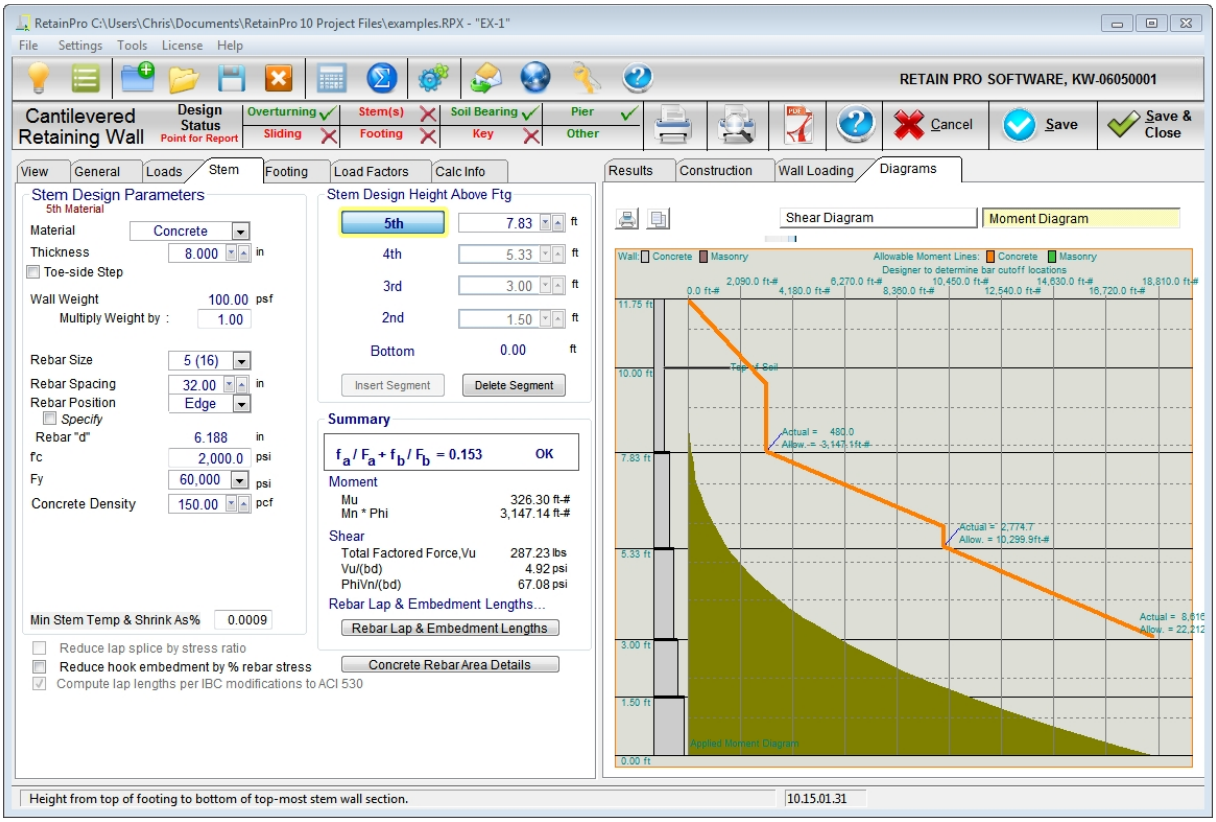
This drawing will not depict the wall in a graphically correct way until sufficient data has been entered. Only a default graphic will appear initially.

4.10 Diagrams Tab

4.10.1 Shear and Moment Diagrams

Shear and Moment Diagrams

These diagrams display applied and resisting moments and shears plotted along the height of the stem.



Each change in section (material, thickness, or reinforcing) is marked.

For concrete stem sections, the applied moments and shears are factored, and resisting moments and shears are design strengths based upon LRFD design.

For masonry stem sections designed according to LRFD, the applied moments and shears are factored, and resisting moments and shears are design strengths. For masonry stem sections designed according to ASD, the applied moments and shears are service-level loads, and resisting moments and shears are allowable strengths.

The moment resisting line is usually sloped to reflect the variation in resisting capacity with reduced remaining rebar development length.

These curves will be useful for visualizing and determining cutoff points for reinforcing, and general viewing of the stem adequacy.

This feature not available for gravity or segmental walls.

4.11 Methodology / Analysis & Design Assumptions

Methodology / Analysis & Design Assumptions

GENERAL:

For cantilever walls the stem is fixed to the footing, the footing is free to rotate on the supporting soil, and no lateral restraint can exist at or near the top of the wall (otherwise it is not a cantilevered wall).

For restrained ("basement" or "tie-back") walls, the program assumes either 100% fixity at the base, or pinned (zero rotational fixity). Lateral support is at or near the top, and moment/shears are computed at the base, maximum positive, and at the upper support. The program does not check flexural stress reduction for axial loads (the unity interaction formula) since in most cases of basement walls the h/t ratio is below about 10 for masonry walls and somewhat higher for concrete, and axial stresses are low. If axial stresses are considered significant (say over 1000 lbs. per ft. length of wall), the interaction should be checked at the point of maximum positive moment.

For restrained walls, the program assumes that the restraint at or near the top is provided by a continuous line of restraint, such as could be provided by continuous connection to a slab or other diaphragm. If the connection between the retaining wall and the restraining diaphragm occurs only at discrete points, the horizontal span of the wall *between* those tieback points may become a design consideration. This potential failure mode would have to be checked by supplemental hand calculations, as the program does not consider this type of behavior.

References used for the development of this program are listed in Appendix E.

Stem design material is limited to concrete or concrete masonry. Design strength of concrete and masonry may be specified.

Conventional "heel" and "toe" terminology is used, whereby the "heel" side of the wall supports the retained earth. In this program, the "heel" distance is measured from the front face of the stem.

Concrete design for stem and footing is based upon ultimate strength design (SD) using factored loads. Factors for various building codes will be displayed on the Load Factors page, and may be edited. Since they are editable, be sure to check them before starting a design since you may have changed them.

Masonry design is based upon the Allowable Stress Design (ASD) or Strength Design (SD), as selected.

A geotechnical engineer will typically have determined design criteria (equivalent fluid pressure, allowable soil bearing pressure, sliding coefficient, etc.). If this is not the case, you can enter the angle of internal friction for the soil, and the program will compute the corresponding active pressure, using the Coulomb formulas based upon the soil density and backfill slope you have specified. If the Coulomb method is chosen, passive pressure will be based upon the Rankine Formula, assuming a level toe-side backfill.

Global stability is not checked.

Weight of concrete block masonry can be lightweight, medium weight, or normal weight, per the table in this User's Manual. Refer to Appendix C.

Horizontal temperature/shrinkage reinforcing is at the discretion of the designer. For horizontal temperature and shrinkage reinforcing for various stems see Appendix A.

Axial loads may be applied to the top of the stem but it is recommended that they do not exceed about 3,000 lbs to avoid reversal of heel bending moment. Slenderness interaction reductions for cantilevered walls are not calculated since h/t ratios are typically less than about 12. Only "positive" eccentricities from the centerline of the top stem are accepted (i.e. toward the toe), since negative eccentricity could lead to unconservative results.

Excessively high axial loads are not anticipated by the program and should not be applied if they would cause tension in the bottom of the footing heel – the program assumes typical retaining wall conditions where the heel moment causes tension at the top of the footing. If a design requires a very high axial load, say, over 3 kips/lf, it is suggested to use footing design software or hand calculations.

Concrete block thicknesses of 6", 8", 10", 12", 14", and 16" are allowed in the program.

Bond stress masonry for masonry stems. Flexural bond is a slipping (grip) stress between reinforcing and grout, resulting from the incremental change in moment from one point to another, and is a function of the total shear at the section. The program does not specifically check bond stress, but does use the formula $\mu = M / (j\, d\, \pi\, d_b)$, and compares this with the allowable development length. The formula for bond, relating to shear, is: $\mu = V / (\Sigma_o\, j\, d)$, where Σ_o is the perimeter of the bar(s) per linear foot. “j” and “d” are the familiar terms. This can be re-written to be approximately: $\mu = 0.35\, V\, s / d_b\, j\, d$, where “s” is the bar spacing in feet and d_b is the bar diameter, if the designer wishes to check to the bond.

Bond stress in masonry retaining walls is of questionable significance since the bars are customarily cast in grout which by code must be at least 2,000 psi, therefore comparable to embedment in concrete. Furthermore, Amrein (see bibliography) quotes a research study concluding the bond stress could be 400 psi based upon experimental studies showing minimum achieved stresses of 1,000 psi, thereby giving the former value a safety factor of 2.5.

This is probably a moot issue since rarely would bond stresses govern over shear stresses, particularly if the stress level in the reinforcing is factored in. Additionally, development lengths for reinforcing in masonry, and code required lap lengths, are considered quite conservative.

Stem reinforcing may be #4 through #10 bars.

Critical section for bending in the footing is at the face of the stem for concrete and 1/4 nominal thickness within the wall for masonry stems. For shear, for both concrete and masonry stems, the critical section is a distance "d" from the face of the stem toward the toe, and at the face of the stem for the heel. The program does not calculate toe or heel bar development lengths inward from the face of the stem (where the moment is maximum). When selecting and detailing the arrangement of toe and heel bars this should be considered. Refer to Appendix B for development lengths in concrete, which can be adjusted for the stress level.

The program calculates the bending in the key and determines whether reinforcing is required. For determining section modulus, 3" is deducted from the key width per ACI recommendation. If reinforcing is required, a message will appear. You can then change the key dimensions until the message disappears, or use the rebar suggestions displayed. The key moment and shear is produced by the passive resisting pressure acting against the key.

Slab restraint at the base can be specified on the Footing > Key Design & Sliding Options tab. The program only allows this restraint to occur at the top of the footing – not higher.

RESTRAINED WALLS:

A vertical component of active pressure is not activated, whether or not it is checked on the General tab, since the top of the wall is assumed not to deflect and thereby not activate such force. Overturning moment is not applicable, and is therefore not displayed, since overturning stability is by restraint at or near the top of the wall.

When 100% Fixity @ Base is selected soil pressures are assumed to be completely uniform.

When 100% Fixity @ Base is **not** selected, and if slab restrains sliding, the soil pressures are calculated considering the following effects:

- Moment on soil due to eccentricity of vertical loads.

When 100% Fixity @ Base is **not** selected, and if no slab restrains sliding, the soil pressures are calculated considering the following effects:

- Moment on soil due to shear times the footing thickness.
- Moment on soil due to eccentricity of vertical loads.

Shear at base of stem is computed based on the summation of all lateral force above that point.

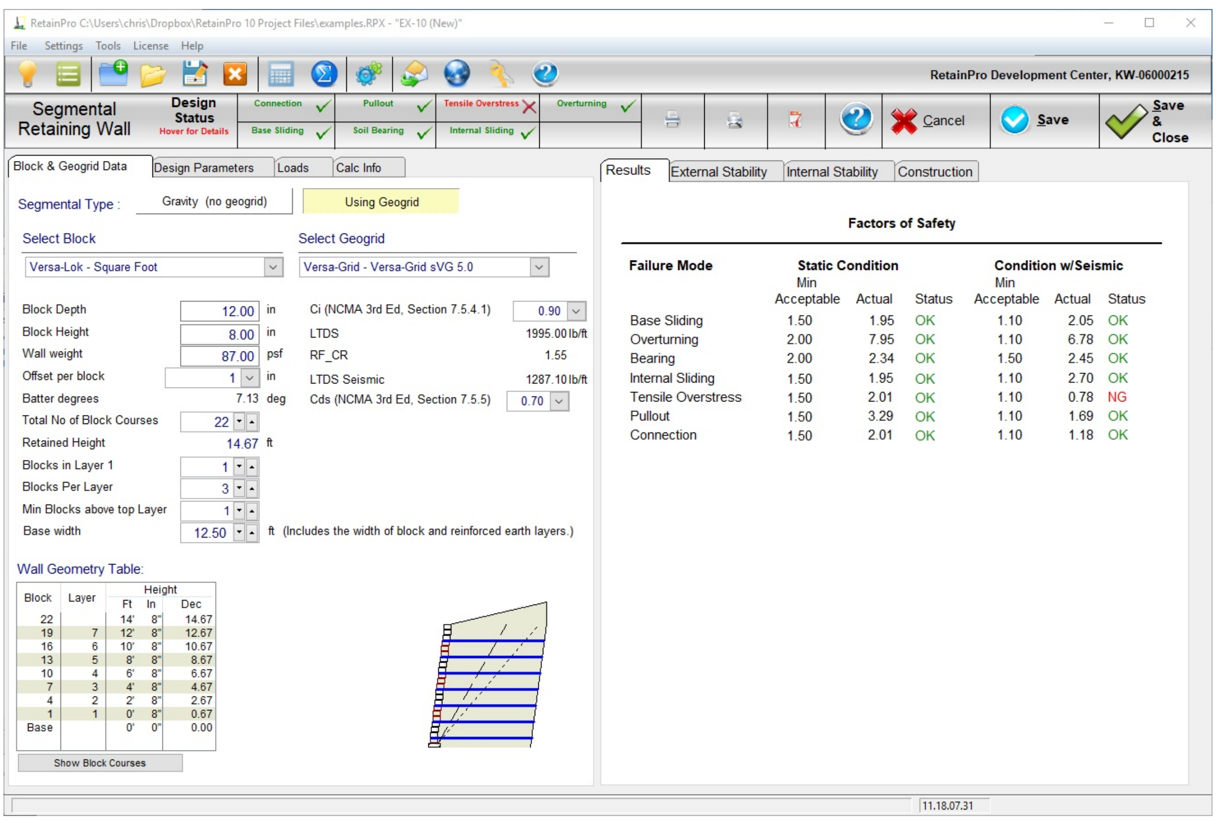
Part V

5 Segmental Walls

5.1 Segmental Wall Overview

Segmental Wall Overview

Segmental walls are constructed of stacked masonry blocks, usually of proprietary configurations, without steel rebar, grouting, or mortar. They are dry-stacked, either vertically or with offsets at each block such that the wall is slightly battered and leans into the earth. When geogrids are used in segmental retaining walls, they are placed in horizontal layers separated by some vertical distance as the wall is constructed and backfilling progresses. Their purpose is to reinforce the earth behind the wall such that the reinforced earth zone acts en masse with the wall to resist sliding and overturning, hence no conventional foundation is required. (These walls are also called MSE – Mechanically Stabilized Earth walls.) The geogrids extend beyond the failure plane and resist pullout by friction resistance due to the weight of soil above. Connection to the wall blocks is achieved through friction between blocks and sometimes by proprietary connection devices.



5.2 Design Assumptions for Geogrid Reinforced Segmental Walls

Design Assumptions for Geogrid Reinforced Segmental Walls

When working with the Geogrid Reinforced Segmental Retaining Wall module in RetainPro the input screens and output report vary from the conventional cantilevered and restrained retaining walls.

In general, methodology used conforms to NCMA's *Design of Segmental Retaining Walls, 3rd Edition.*

Since segmental geogrid reinforced retaining walls can be highly complex, some simplifying design assumptions have been implemented to make the program easier to use and still cover most conditions encountered. These assumptions are:

1. All masonry units are the same size (height, width, depth) and single wythe.
2. Offsets between blocks are uniform for the full height of the wall.
3. Spacing of geogrid layers may be specified (number of blocks between layers), but spacing is constant except for lowest layer and above uppermost layer.
4. Lengths of geogrids are constant for all layers.
5. Same geogrid material is used for all layers.
6. Coulomb method is used for determining lateral earth pressures.
7. Overall wall height is limited to 30 feet.
8. Setting base is assumed to be gravel or crushed stone, 6" thick, and extending 6" beyond each edge of the bottom block.
9. Block dimensions are obtained from vendor websites or literature.
10. Weight of wall is assumed to be 120 pcf for depth of block.
11. Geogrid Long Term Design Strength and connection values have been obtained from vendor websites or vendor ES-ICC Evaluation Reports. Verification with vendor is recommended.

5.3 Design Assumptions for Gravity Segmental Retaining Walls

Design Assumptions for Gravity Segmental Retaining Walls

When working with the Geogrid Reinforced Segmental Retaining Wall module in RetainPro the input screens and output report vary from the conventional cantilevered and restrained retaining walls.

In general, methodology used conforms to NCMA's *Design of Segmental Retaining Walls, 3rd Edition.*

Since segmental retaining walls can be highly complex, some simplifying design assumptions have been implemented to make the program easier to use and still cover most conditions encountered. These assumptions are:

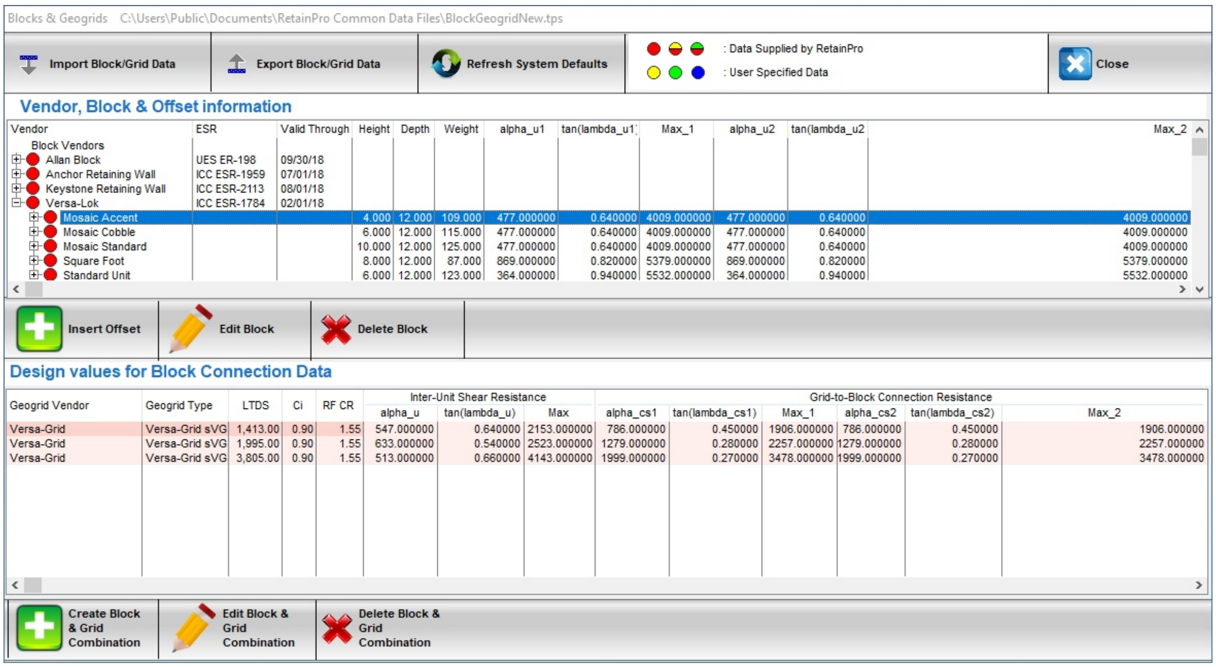
1. All masonry units are the same size (height, width, depth) and single wythe.
2. Offsets between blocks are uniform for the full height of the wall.
3. Coulomb method is used for determining lateral earth pressures.
4. Setting base is assumed to be gravel or crushed stone, 6" thick, and extending 6" beyond each edge of the bottom block.
5. Block dimensions are obtained from vendor websites or literature.
6. Weight of wall is assumed to be 120 pcf for depth of block.

5.4 Block & Geogrid Editor

Block & Geogrid Editor

Click Tools > Block & Geogrid Editor.

The Block & Geogrid Editor is used to pair block data with geogrid data, to create viable design combinations in the geogrid reinforced Segmental Retaining Wall module. The editor allows the user to add, edit, or delete block vendors, blocks, block offset values, and then add, edit, or delete geogrid design data for use with each type of block.



Overview: The editor shows a list of block vendors on the top of the screen. Expanding any of the block vendors will reveal the individual block types offered by that vendor. Expanding any of the individual block types will reveal the list of applicable offset values that can be used for a wall assembled with that block type. Clicking on any individual block type will display the list of geogrids that have published design values for use with the selected block. Any combination of block and geogrid that is visible in the editor will be available for selection in the geogrid reinforced Segmental Retaining Wall module.

The functions of the various tools and buttons on the Block & Geogrid Editor are described below:

Import Block/Grid Data: Allows the user to import a file (such as from a colleague) that contains all of the block and grid data from another RetainPro installation.

Export Block/Grid Data: Allows the user to export a file that contains all of the block and grid data from the current RetainPro installation (such as to share with a colleague).

Refresh System Defaults: Allows the user to reset the design values for block and grid to the initial values as they were when the software was originally installed. This function is safe to use even if the user has created any custom block/grid definitions after installation, because the system automatically differentiates between system-installed data and custom user data. This function will ***not*** alter or remove your custom user data if any has been entered.

Insert Vendor/Insert Block/Insert Offset: The function of this button changes depending upon what is selected in the top pane.

- When the focus is on the label "Block Vendors" at the top of the tree, this button takes the form of Insert Vendor, and it allows a new block vendor to be added to the tree structure.
- When the focus is on any one of the block vendors in the tree, this button takes the form of Insert Block, and it allows a new block type to be added to the selected vendor.
- When the focus is on any one of the blocks in the tree, this button takes the form of Insert Offset, and it allows a new offset value to be added to the selected block.

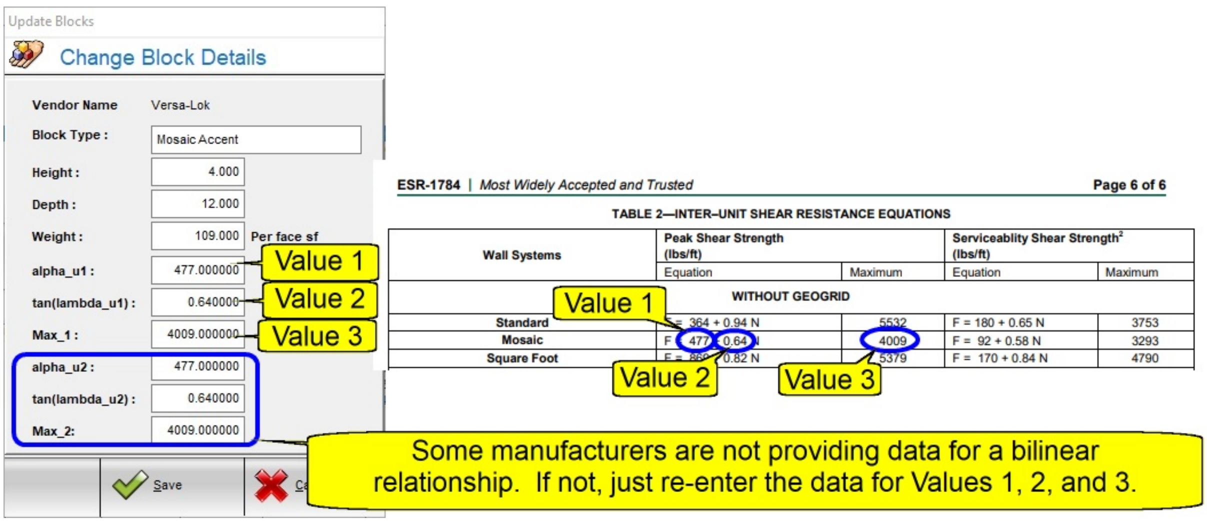
Edit Vendor/Edit Block/Edit Offset: The function of this button changes depending upon what is selected in the top pane.

- When the focus is on any one of the block vendors in the tree, this button takes the form of Edit Vendor, and it allows the selected vendor name and website to be edited.
- When the focus is on any one of the blocks in the tree, this button takes the form of Edit Block, and it

allows the selected block properties to be edited.

- When the focus is on one of the offset values, this button takes the form of Edit Offset, and it allows the selected offset value to be edited.

When editing block definitions, the program presents the following dialog:



Delete Vendor/Delete Block/Delete Offset: The function of this button changes depending upon what is selected in the top pane.

- When the focus is on any one of the block vendors in the tree, this button takes the form of Delete Vendor, and it allows the selected vendor to be deleted.
- When the focus is on any one of the blocks in the tree, this button takes the form of Delete Block, and it allows the selected block to be deleted.
- When the focus is on one of the offset values, this button takes the form of Delete Offset, and it allows the selected offset value to be deleted.

Create Block & Grid Combination: When the focus on the top of the screen is on any one of the blocks in the tree, this button allows the user to define a new geogrid/block combination by specifying geogrid vendor, type, and design properties for use with the selected block. It also provides access to the Edit Geogrid Design Data button that allows the user to edit LTDS, Ci and RF_{CR} values for the selected geogrid (see next item).

Edit Block & Grid Combination: When the focus on the top of the screen is on any one of the blocks in the tree, this button allows the user to edit the connection design properties for use with the selected block/geogrid combination. When editing Block Connection Data for the selected block/geogrid combination, the program presents the following dialog:

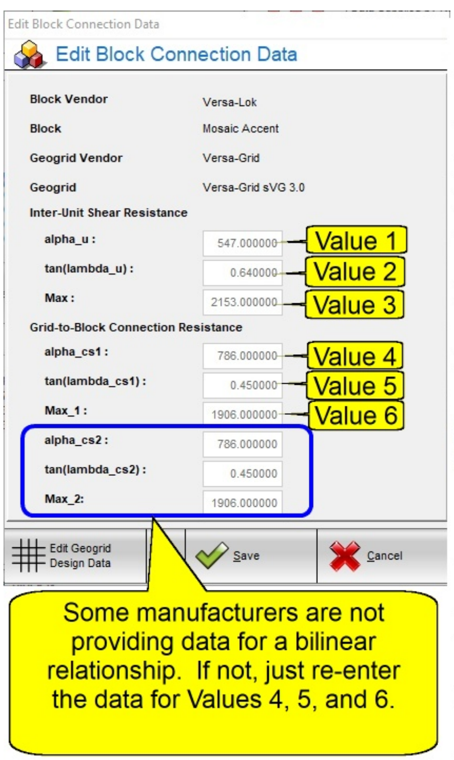


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TABLE 2—INTER–UNIT SHEAR RESISTANCE EQUATIONS

Wall Systems		Peak Shear Strength (lbs/ft) Equation	Maximum	Serviceablity Shear Strength[2] (lbs/ft) Equation	Maximum
WITHOUT GEOGRID					
Standard		F = 364 + 0.94 N	5532	F = 180 + 0.65 N	3753
Mosaic		F = 477 + 0.64 N	4009	F = 92 + 0.58 N	3293
Square Foot		F = 869 + 0.82 N	5379	F = 170 + 0.84 N	4790
WITH GEOGRID					
Standard	Versa-Grid sVG 3.0	F = 401 + 0.75 N	2274	F = 230 + 0.68 N	1928
	Versa-Grid s[illegible]	[illegible]	[illegible]	[illegible]271 + 0.49 N	1987
	Versa-Grid s[illegible]	[illegible]	[illegible]	[illegible]07 + 0.57 N	3532
Mosaic	Versa-Grid sVG 3.0	F = 547 + 0.64 N	2153	F = 19 + 066 N	1675
	Versa-Grid sVG 5.0	F = 633+ 0.54 N	2523	F = 17 + 0.65 N	2292
	Versa-Grid sVG 8.0	F = 513 + 0.66 N	4143	F = 214 + 0.63 N	3679
Square Foot	Versa-Grid sVG 3.0	F = 532 + 0.68 N	2223	F = 9 + 0.7 N	1824
	Versa-Grid sVG 5.0	F = 790 + 0.58 N	2812	F = 7 + 0.7 N	2447
	Versa-Grid sVG 8.0	F = 1031 + 0.53 N	3942	F = 837 + 0.46 N	3363

For **SI**: 1 lb/linear foot = 14.6N/m

[1]The inter-unit shear resistance F [lb/linear foot (N/m)] of the Versa-Lok System at any depth is a function of superimposed normal (applied) load, N [lb/linear foot N/m)].
[2]The serviceability shear strength is based on prescribed deformation criterion, which is either ¾ inch (19 mm) or a value equal to 2 percent of the unit height, whichever is less.

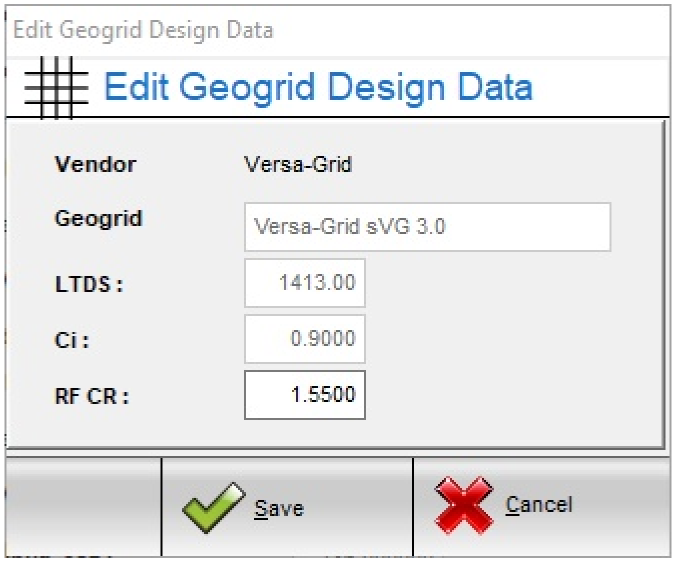
TABLE 3—GEOGRID-TO-BLOCK PULLOUT RESISTANCE EQUATIONS[1]

Wall Systems		Peak Connection Strength (lbs/ft) Equation	Maximum	Serviceablity Connection Strength (lbs/ft)[2] Equation	Maximum
Standard	Versa-Grid sVG 3.0	F = 519 + 0.23 N	1086	F = 515 + 0.07 N	687
	Versa-Grid s[illegible]	[illegible]	[illegible]	[illegible]126 + 0.39 N	1491
	Versa-Grid s[illegible]	[illegible]	[illegible]	[illegible]280 + 0.21 N	1435
Mosaic	Versa-Grid sVG 3.0	F = 786 + 0.45 N	1906	F = 708 + 0.25 N	1330
	Versa-Grid sVG 5.0	F = 1279 + 0.28 N	2257	F = 778 + 0.3 N	1826
	Versa-Grid sVG 8.0	F = 1999 + 0.27 N	3478	F = 1034 + 0.15 N	1855
Square Foot	Versa-Grid sVG 3.0	F = 1003 + 0.23 N	1577	F = 601 + 0.25 N	1225
	Versa-Grid sVG 5.0	F = 1625 + 0.36 N	2885	F = 1127 + 0.15N	1652
	Versa-Grid sVG 8.0	F = 1713 + 0.36 N	3700	F = 1159 + 0.04 N	1380

For **SI**: 1 lb/linear foot = 14.6N/m.

[1]Where N = superimposed normal (applied) load (lb/linear foot of geogrid measured along the wall length direction).
[2]The serviceability connection strength is based on a maximum ¾ inch (19 mm) of geogrid displacement.

This dialog also provides access to the Edit Geogrid Design Data button that allows the user to edit the LTDS, Ci and RF_{CR} values for the selected geogrid. When editing Geogrid Design Data for the selected geogrid, the program presents the following dialog:



Delete Block & Grid Combination: When the focus on the top of the screen is on any one of the blocks in the tree, this button allows the user to delete the selected block/geogrid design combination. (Note: This does not delete the selected block from the block database, nor does it delete the selected geogrid from the geogrid database. It merely removes the *combination* of the selected block and grid from the list of available assemblies to choose from.)

Disclaimer: The design values for block/grid combinations have a direct and significant influence on the results produced in the Segmental Retaining Wall module. The licensed practicing professional user must therefore exercise due caution when editing values in the data table and when incorporating this data into subsequent calculations. We strongly recommend that all block & geogrid design values be obtained from test reports that are acceptable to the code enforcement agency where the wall will be constructed. The design values in this program are supplied as a convenience to the user and must be verified with the manufacturers, test reports and code agencies.

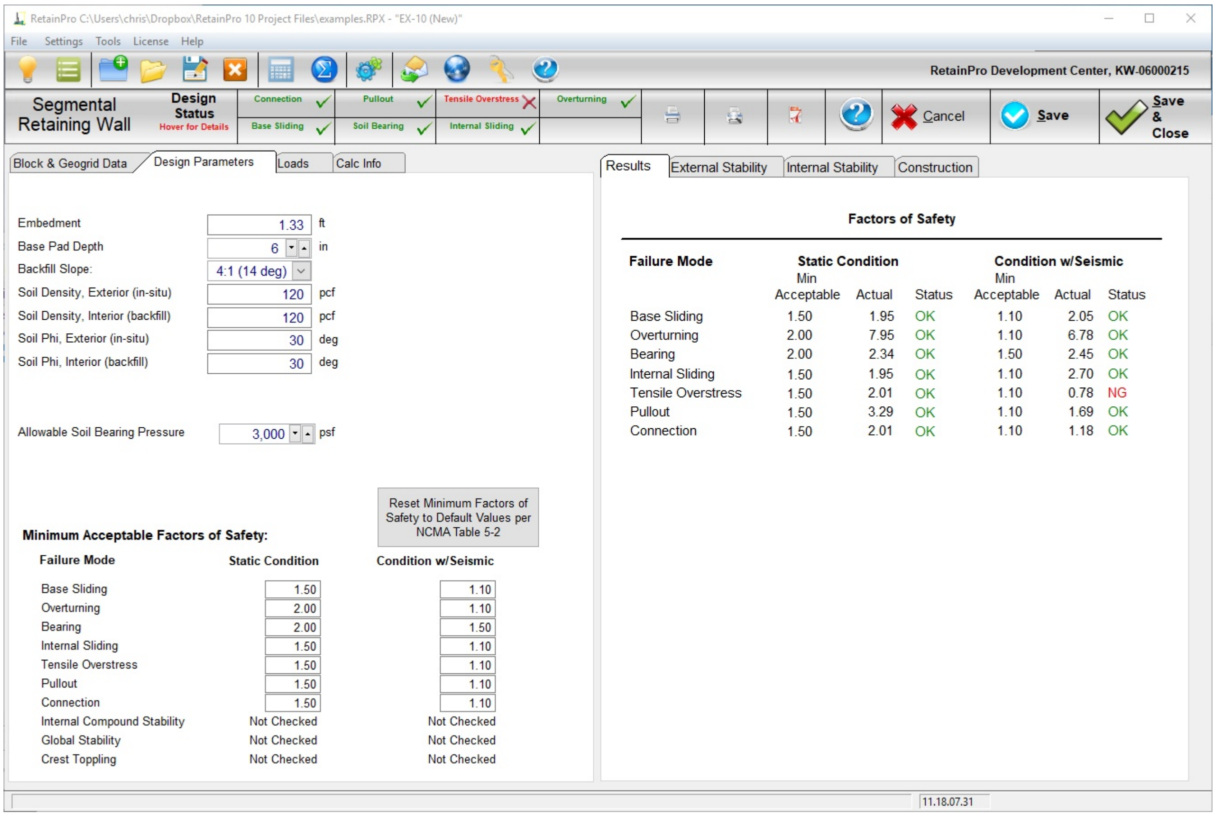
Inserting Custom Block and Geogrid:

The procedure to add a new block and geogrid is as follows:

1. Open RetainPro, but do not open a Project File.
2. Click Tools > Block & Geogrid Editor.
3. Click Insert Vendor and add a vendor for the new block.
4. Click on the new block vendor and click Insert Block.
5. Enter the new block data and click the Save button.
6. Select the new block and click Insert Offset.
7. Enter an offset value and click the Save button.
8. Click on the block again and click Create Block & Grid Combination.
9. Click the ... button next to Geogrid Vendor Name and either select an existing geogrid vendor or click Insert button and enter a new geogrid vendor name.
10. Click the ... button next to Geogrid Type and either select an existing geogrid or click the Add button, and enter the name and data for the new geogrid.
11. Click the Select button.
12. Enter the necessary values.
13. Click the Save button.
14. The new combination of block and grid with connection data appears in the list on the bottom, and is available for selection in the Segmental Retaining Wall module.

5.5 Design Parameters Tab

Design Parameters Tab



Retained Height: Displays the retained height based on block coursing and geometry entered on the Block & Geogrid tab.

Embedment: Depth below grade (on the low side) to top of setting pad. Usually one block course or 1'-0".

Base Pad Depth: Thickness of the base pad.

Backfill Slope: Select the backfill slope from the drop-down list box.

Soil Density, Exterior (in-situ): Enter the density of the native soil beyond the backfill zone and under the base.

Soil Density, Interior (backfill): Enter the density of the backfill material (typically granular soil or gravel).

Soil Phi, Exterior (in-situ): Enter the angle of internal friction of in-situ soil.

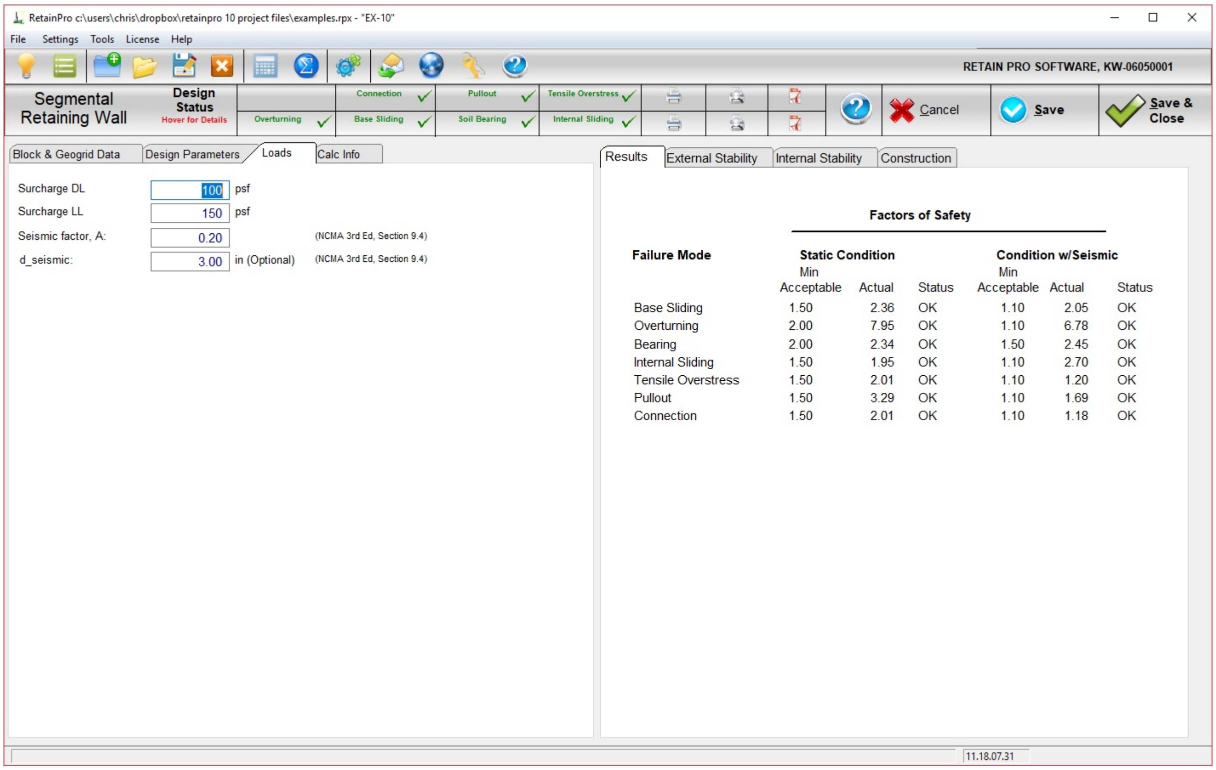
Soil Phi, Interior (backfill): Enter the angle of internal friction of the backfill soil.

Allowable Soil Bearing Pressure: Enter the allowable soil bearing pressure.

Minimum Acceptable Factors of Safety: Specify the minimum acceptable factors of safety for each of the different failure modes, or click the reset button to easily reset all values to defaults as per NCMA Table 5-2.

5.6 Loads Tab

Loads Tab



Surcharge DL, psf: Enter the dead load surcharge.

Surcharge LL, psf: Enter the live load surcharge – it will not be used to resist overturning or sliding.

Seismic A factor: Specified horizontal peak ground acceleration expressed as a fraction of the gravitational constant, g. The site-specific values of A represent a 90% probability of that value not being exceeded in 50 years. See NCMA 3rd Edition, Section 9.4.

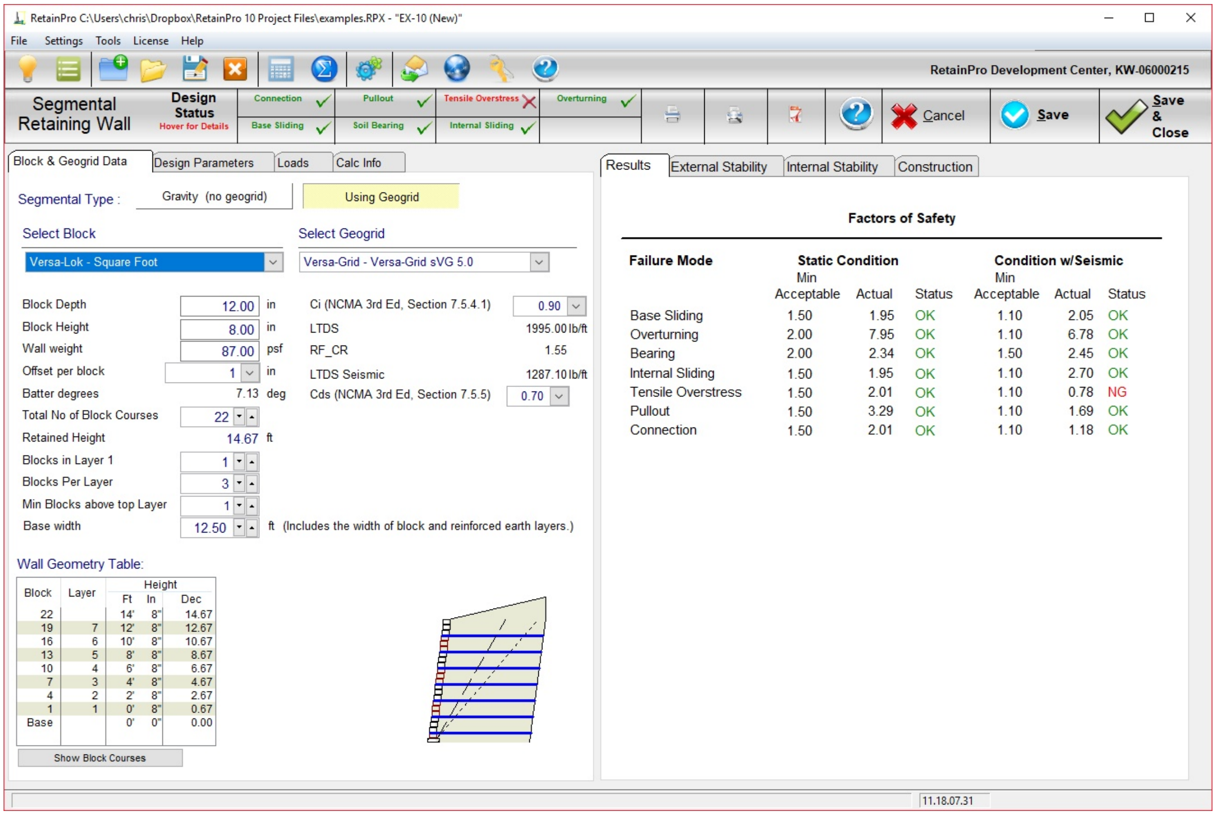
$d_{seismic}$: The lateral deflection that the retaining wall can withstand during a seismic event, in units of inches. See NCMA 3rd Edition, Section 9.4. Note that this input is optional. If a non-zero value is entered, the program will apply the formulas that consider the maximum permissible deformation. If the value is left zero (blank), the program will apply the formulas that are independent of the deformation.

5.7 Geogrid Reinforced Segmental Retaining Walls

Geogrid Reinforced Segmental Retaining Walls

5.7.1 Block & Geogrid Data Tab (for Geogrid Reinforced Walls)

Block & Geogrid Data Tab (for Geogrid Reinforced Walls)



Segmental Type: Select either Gravity or Geogrid.

Total No of Block Courses: Enter the number of block courses.

Blocks in Layer 1: Enter the number of courses below the first layer of geogrid.

Blocks per Layer: Enter the typical number of courses between layers of geogrid.

Min Blocks above top Layer: Enter the minimum number of courses above the top layer of geogrid.

Base Width: Enter the full base width including wall depth. (usually 60% - 70% of retained height).

Select Block: From the drop down menu select the vendor and block you want to use. Selecting a block will insert its values into the criteria below.

Block depth, in: This will be automatically input based upon block selection.

Block height, in: This will be automatically input based upon block selection.

Wall weight, psf: This will be automatically input. Note that the full block depth is assumed to be in-filled and an average density of 120 pcf is used. Note that block weight is in units of psf. Think of looking at an elevation of a constructed wall. It is the weight of one square foot of finished wall. It is calculated by knowing the weight of the solid portion of the block and assuming that any hollow portions are filled with material that weighs 120 pcf.

Offset per block, in: Select this value from the drop down menu – it is vendor-dependent.

Batter, degrees: This angle will be computed and displayed based upon offset and block height entered.

Select Geogrid: From the drop down menu select the geogrid vendor and the specific geogrid. Design parameters will be displayed below.

Ci factor: Select the coefficient of interaction for pullout (usually 0.70 – 0.90). Note: The program will not permit a layer of geogrid to be placed under the first course, so the value of Cds, coefficient of direct sliding is hard coded to 1.0 for external sliding checks.

LTDS, lbs/ft: Long Term Design Strength will be automatically inserted based upon the vendor/geogrid selection.

RF_{CR}: Creep Reduction Factor will be automatically inserted based upon the vendor/geogrid selection.

$LTDS_{seismic}$, lbs/ft: Long Term Design Strength for seismic loading will be automatically calculated as LTDS / RF_{CR}.

C_{DS}: Select the coefficient of direct sliding. Reference NCMA 3rd Edition, Section 7.5.5.

Wall Geometry Table:

Block: Displays the total number of block courses.

Layer: Displays the geogrid layer numbers in ascending order from bottom.

Height: Displays block and layer heights in ft-inches and decimals.

Show Block Courses / Show Grid Layers: Toggles between the display of block courses or grid layers.

5.7.2 Results Tab (for Geogrid Reinforced Walls)

Results Tab (for Geogrid Reinforced Walls)

Results | External Stability | Internal Stability | Construction

Factors of Safety

Failure Mode	**Static Condition** Min Acceptable	Actual	Status	**Condition w/Seismic** Min Acceptable	Actual	Status
Base Sliding	1.50	1.95	OK	1.10	2.05	OK
Overturning	2.00	7.95	OK	1.10	6.78	OK
Bearing	2.00	2.34	OK	1.50	2.45	OK
Internal Sliding	1.50	1.95	OK	1.10	2.70	OK
Tensile Overstress	1.50	2.01	OK	1.10	0.78	NG
Pullout	1.50	3.29	OK	1.10	1.69	OK
Connection	1.50	2.01	OK	1.10	1.18	OK

Results Tab

Displays the minimum acceptable factor of safety and the minimum actual factor of safety for all failure modes, for the static condition and for the condition that includes seismic loading.

5.7.3 External Stability Tab (for Geogrid Reinforced Walls)

External Stability Tab (for Geogrid Reinforced Walls)

Results | External Stability | Internal Stability | Construction

Stability

Base Sliding Force (w/o Seismic)	6,321.38	lb
Base Resisting Force (w/o Seismic)	14,895.44	lb
Base Sliding (w/o Seismic) FS	2.36	
Base Sliding Force (w/ Seismic)	7,345.28	lb
Base Resisting Force (w/ Seismic)	15,058.43	lb
Base Sliding (w/ Seismic) FS	2.05	
Overturning Moment (w/o Seismic)	40,493.22	ft lb
Resisting Moment (w/o Seismic)	322,106.64	ft lb
Overturning (w/o Seismic) FS	7.95	
Overturning Moment (w/ Seismic)	48,106.08	ft lb
Resisting Moment (w/ Seismic)	325,944.89	ft lb
Overturning (w/ Seismic) FS	6.78	
Applied Bearing Pressure (w/o Seismic)	1,279.80	psf
Allowable Bearing Pressure (w/o Seismic)	3,000.00	psf
Bearing (w/o Seismic) FS	2.34	
Applied Bearing Pressure (w/ Seismic)	1,224.22	psf
Allowable Bearing Pressure (w/ Seismic)	3,000.00	psf
Bearing (w/ Seismic) FS	2.45	
Eccentricity of Vert. Force (w/o Seismic)	4.67	ft
Effective Base Width (w/o Seismic)	21.83	ft
Eccentricity of Vert. Force (w Seismic)	4.40	ft
Effective Base Width (w Seismic)	21.31	ft

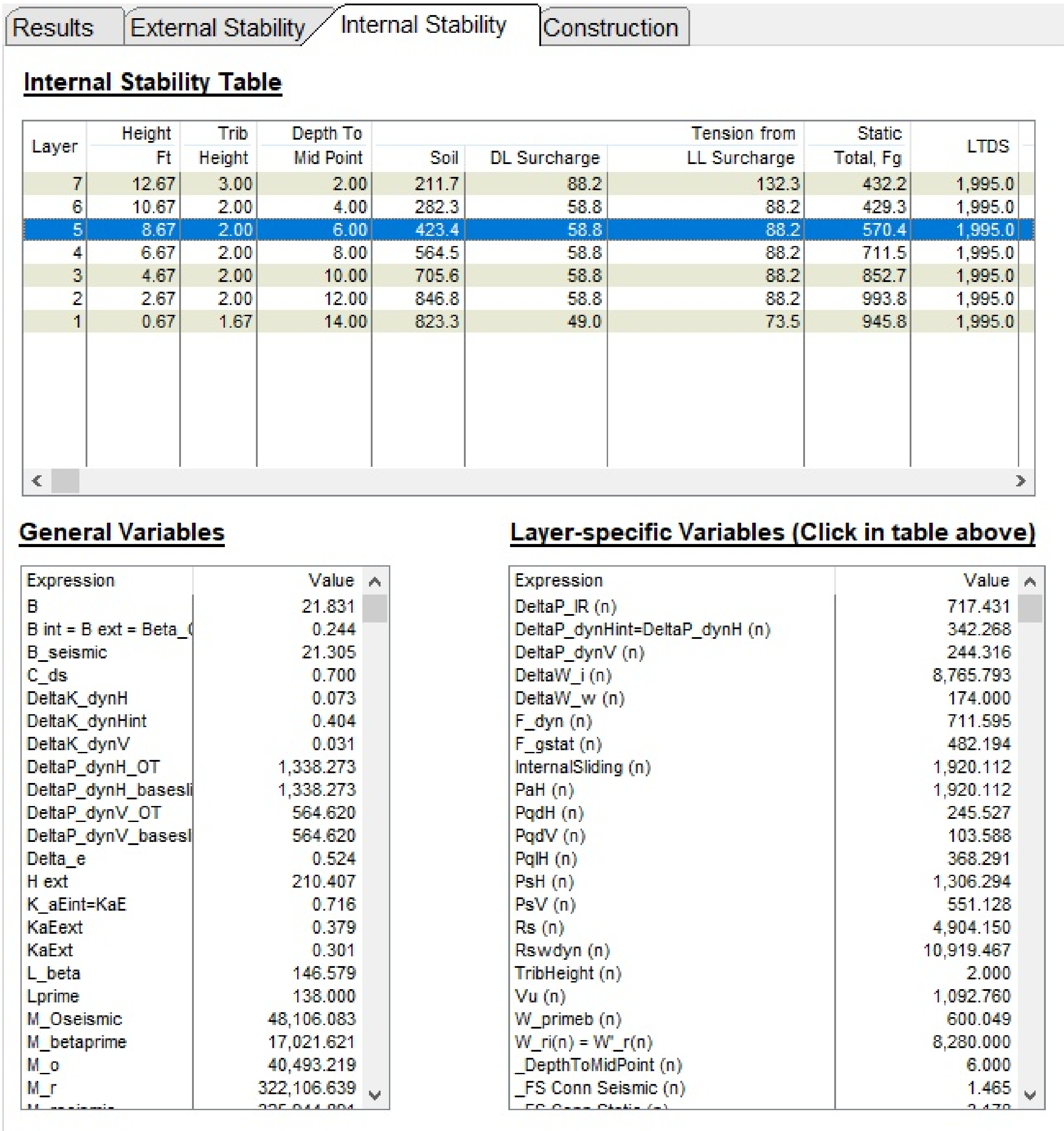
External Stability Tab

Displays overturning and sliding factors of safety as well as bearing pressure results for conditions with and without seismic loading.

Also reports eccentricity of vertical force and effective base width.

5.7.4 Internal Stability Tab (for Geogrid Reinforced Walls)

Internal Stability Tab (for Geogrid Reinforced Walls)



Results | External Stability | Internal Stability | Construction

Internal Stability Table

Layer	Height Ft	Trib Height	Depth To Mid Point	Soil	DL Surcharge	Tension from LL Surcharge	Static Total, Fg	LTDS
7	12.67	3.00	2.00	211.7	88.2	132.3	432.2	1,995.0
6	10.67	2.00	4.00	282.3	58.8	88.2	429.3	1,995.0
5	8.67	2.00	6.00	423.4	58.8	88.2	570.4	1,995.0
4	6.67	2.00	8.00	564.5	58.8	88.2	711.5	1,995.0
3	4.67	2.00	10.00	705.6	58.8	88.2	852.7	1,995.0
2	2.67	2.00	12.00	846.8	58.8	88.2	993.8	1,995.0
1	0.67	1.67	14.00	823.3	49.0	73.5	945.8	1,995.0

General Variables

Expression	Value
B	21.831
B int = B ext = Beta_(	0.244
B_seismic	21.305
C_ds	0.700
DeltaK_dynH	0.073
DeltaK_dynHint	0.404
DeltaK_dynV	0.031
DeltaP_dynH_OT	1,338.273
DeltaP_dynH_basesli	1,338.273
DeltaP_dynV_OT	564.620
DeltaP_dynV_basesl	564.620
Delta_e	0.524
H ext	210.407
K_aEint=KaE	0.716
KaEext	0.379
KaExt	0.301
L_beta	146.579
Lprime	138.000
M_Oseismic	48,106.083
M_betaprime	17,021.621
M_o	40,493.219
M_r	322,106.639

Layer-specific Variables (Click in table above)

Expression	Value
DeltaP_IR (n)	717.431
DeltaP_dynHint=DeltaP_dynH (n)	342.268
DeltaP_dynV (n)	244.316
DeltaW_i (n)	8,765.793
DeltaW_w (n)	174.000
F_dyn (n)	711.595
F_gstat (n)	482.194
InternalSliding (n)	1,920.112
PaH (n)	1,920.112
PqdH (n)	245.527
PqdV (n)	103.588
PqlH (n)	368.291
PsH (n)	1,306.294
PsV (n)	551.128
Rs (n)	4,904.150
Rswdyn (n)	10,919.467
TribHeight (n)	2.000
Vu (n)	1,092.760
W_primeb (n)	600.049
W_ri(n) = W'_r(n)	8,280.000
_DepthToMidPoint (n)	6.000
_FS Conn Seismic (n)	1.465

Internal Stability Tab

Displays internal stability table:

Layer: Displays geogrid layer numbers.

Height, ft: Displays the height from the base to the elevation of each geogrid layer.

Trib Height: Displays the tributary height of each geogrid layer.

Depth to Midpoint: Displays the distance from the top of the wall to each geogrid layer.

Tension from Soil: Displays the tension in each layer of geogrid due to lateral earth pressure from the soil.

Tension from DL Surcharge: Displays the tension in each layer of geogrid due to lateral earth pressure from a dead load surcharge.

Tension from LL Surcharge: Displays the tension in each layer of geogrid due to lateral earth pressure from a live load surcharge.

Static Total Tension, Fg: The sum of Tension from Soil plus Tension from DL Surcharge plus Tension from LL Surcharge.

LTDS: Echoes the Long Term Design Strength of the selected geogrid.

$LTDS_{seismic}$: Echoes the Long Term Design Strength for seismic design of the selected geogrid.

Total Tension (w/ Seismic), Fi: Total tension in the geogrid when subjected to the load condition that includes seismic loading.

FS Tensile Overstress (static): LTDS / Static Total Tension

FS Tensile Overstress (w/ seismic): $LTDS_{seismic}$ / Total Tension (w/ seismic), Fi

Pullout Strength: Ability of the geogrid to resist pullout failure.

FS Pullout (static): Pullout Strength / Static Total Tension, Fg

FS Pullout (w/ seismic): Pullout Strength / Total Tension (w/ seismic), Fi

Connection Strength: Connection strength of the selected block/geogrid combination.

FS Connection (static): Connection capcacity / Static Total Tension, Fg

FS Connection (w/ seismic): Connection capcacity / Total Tension (w/ seismic), Fi

Internal Sliding Force (static): The driving force at each layer of geogrid from static loading tending to cause the soil mass above to slide sideways.

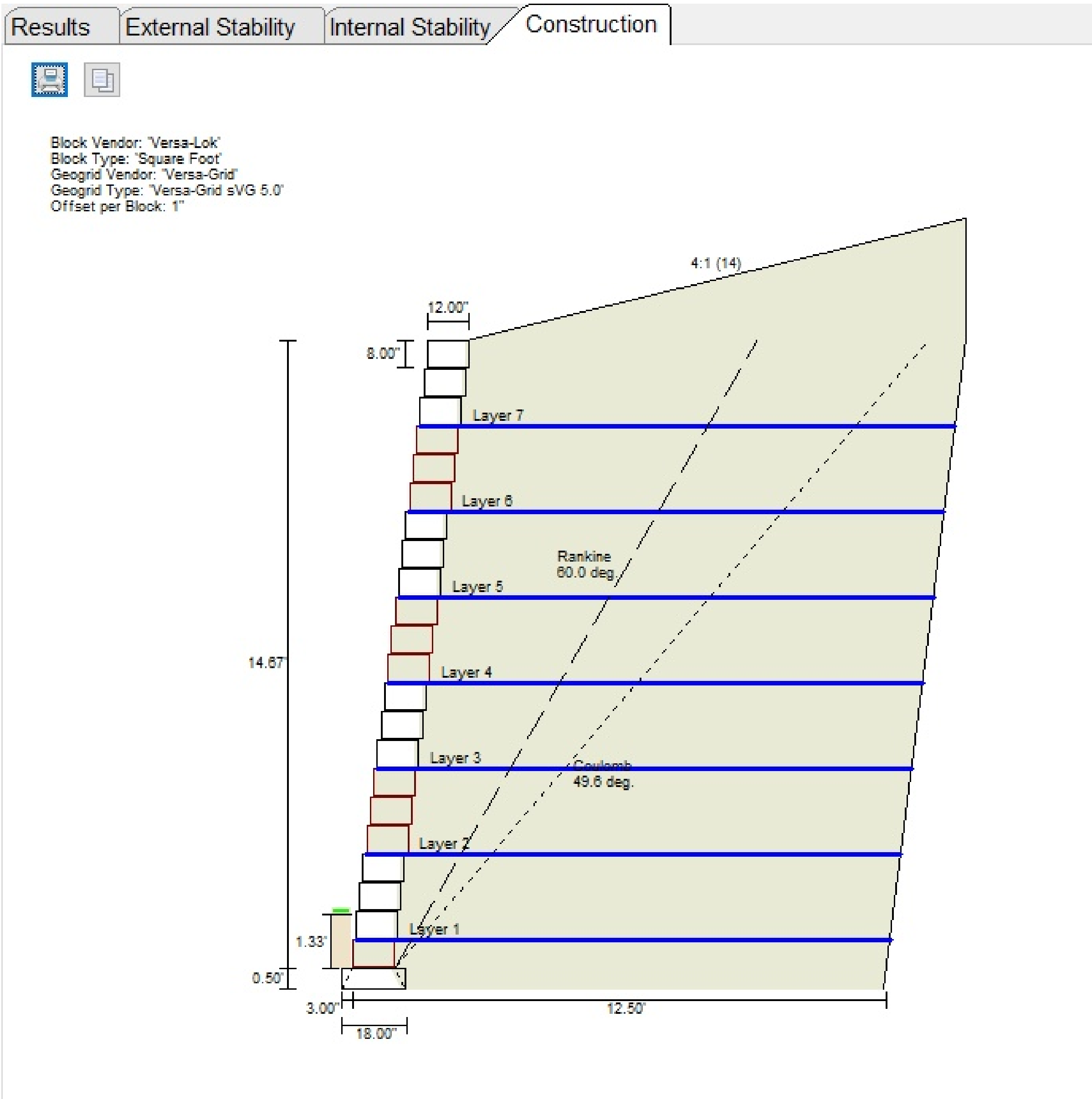
FS Internal Sliding (static): Internal sliding resistance / Static internal sliding force

Internal Sliding Force (w/ seismic):The driving force at each layer of geogrid from loading including seismic tending to cause the soil mass above to slide sideways.

FS Internal Sliding (w/ seismic): Internal sliding resistance / Internal sliding force (w/ seismic)

5.7.5 Construction Tab (for Geogrid Reinforced Walls)

Construction Tab (for Geogrid Reinforced Walls)



Construction Tab

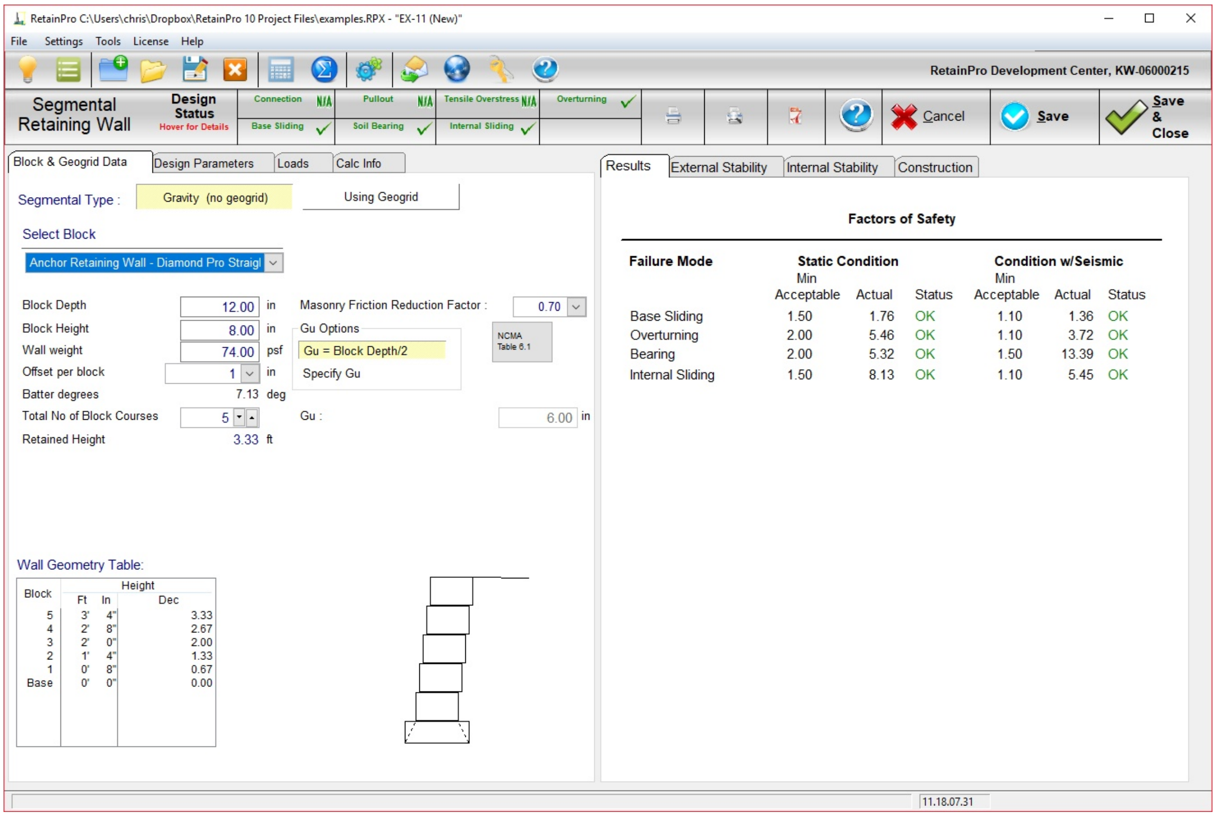
Displays schematic drawing of wall, reinforced area, geogrid layers, dimensions, and failure lines for both Rankine and Coulomb methods.

5.8 Gravity Segmental Retaining Walls

Gravity Segmental Retaining Walls

5.8.1 Block & Geogrid Data Tab for Gravity Walls

Block & Geogrid Data Tab (for Gravity Segmental Retaining Walls)



Segmental Type: Select either Gravity or Geogrid.

Total No of Block Courses: Enter the number of block courses.

Select block: From the drop down menu select the vendor and block you want to use. Selecting a block will insert its values into the criteria below.

Block Depth, in: This will be automatically input based upon block selection.

Block Height, in: This will be automatically input based upon block selection.

Wall weight, psf: This will be automatically input. Note that the full block depth is assumed to be in-filled and an average density of 120 pcf is used. Note that block weight is in units of psf. Think of looking at an elevation of a constructed wall. It is the weight of one square foot of finished wall. It is calculated by knowing the weight of the solid portion of the block and assuming that any hollow portions are filled with material that weighs 120 pcf.

Offset per block, in: Select this value from the drop down menu – it is vendor dependent.

Batter, degrees: This angle will be computed and displayed based upon offset and block height entered.

Masonry Friction Reduction Factor: Select the desired Masonry Friction Reduction Factor. (The adjacent button offers a quick view of NCMA Table 6.1 for some guidance on this factor.)

Gu Options: Select the desired method of calculating/specifying the value of Gu.

Wall Geometry Table:

Block: Displays the total number of block courses.

Height: Displays block and layer heights in ft-inches and decimals.

5.8.2 Results Tab (for Gravity Segmental Retaining Walls)

Results Tab (for Gravity Segmental Retaining Walls)

Results | External Stability | Internal Stability | Construction

Factors of Safety

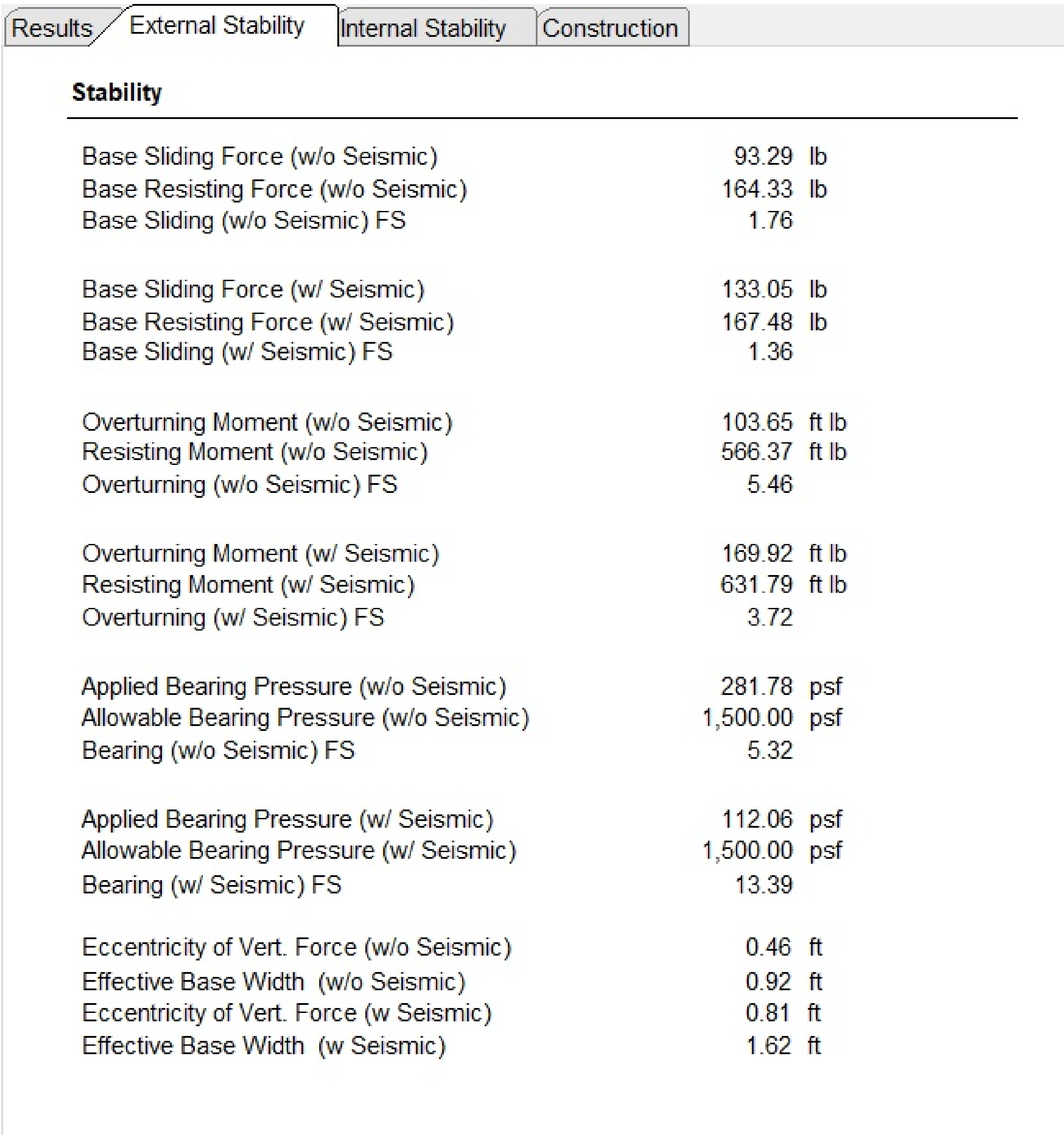
Failure Mode	Static Condition			Condition w/Seismic		
	Min Acceptable	Actual	Status	Min Acceptable	Actual	Status
Base Sliding	1.50	1.76	OK	1.10	1.36	OK
Overturning	2.00	5.46	OK	1.10	3.72	OK
Bearing	2.00	5.32	OK	1.50	13.39	OK
Internal Sliding	1.50	8.13	OK	1.10	5.45	OK

Results Tab

Displays the minimum acceptable factor of safety and the minimum actual factor of safety for all applicable failure modes, for the static condition and for the condition that includes seismic loading.

5.8.3 External Stability Tab (for Gravity Segmental Retaining Walls)

External Stability Tab (for Gravity Segmental Retaining Walls)



Base Sliding Force (w/o Seismic)	93.29	lb
Base Resisting Force (w/o Seismic)	164.33	lb
Base Sliding (w/o Seismic) FS	1.76	
Base Sliding Force (w/ Seismic)	133.05	lb
Base Resisting Force (w/ Seismic)	167.48	lb
Base Sliding (w/ Seismic) FS	1.36	
Overturning Moment (w/o Seismic)	103.65	ft lb
Resisting Moment (w/o Seismic)	566.37	ft lb
Overturning (w/o Seismic) FS	5.46	
Overturning Moment (w/ Seismic)	169.92	ft lb
Resisting Moment (w/ Seismic)	631.79	ft lb
Overturning (w/ Seismic) FS	3.72	
Applied Bearing Pressure (w/o Seismic)	281.78	psf
Allowable Bearing Pressure (w/o Seismic)	1,500.00	psf
Bearing (w/o Seismic) FS	5.32	
Applied Bearing Pressure (w/ Seismic)	112.06	psf
Allowable Bearing Pressure (w/ Seismic)	1,500.00	psf
Bearing (w/ Seismic) FS	13.39	
Eccentricity of Vert. Force (w/o Seismic)	0.46	ft
Effective Base Width (w/o Seismic)	0.92	ft
Eccentricity of Vert. Force (w Seismic)	0.81	ft
Effective Base Width (w Seismic)	1.62	ft

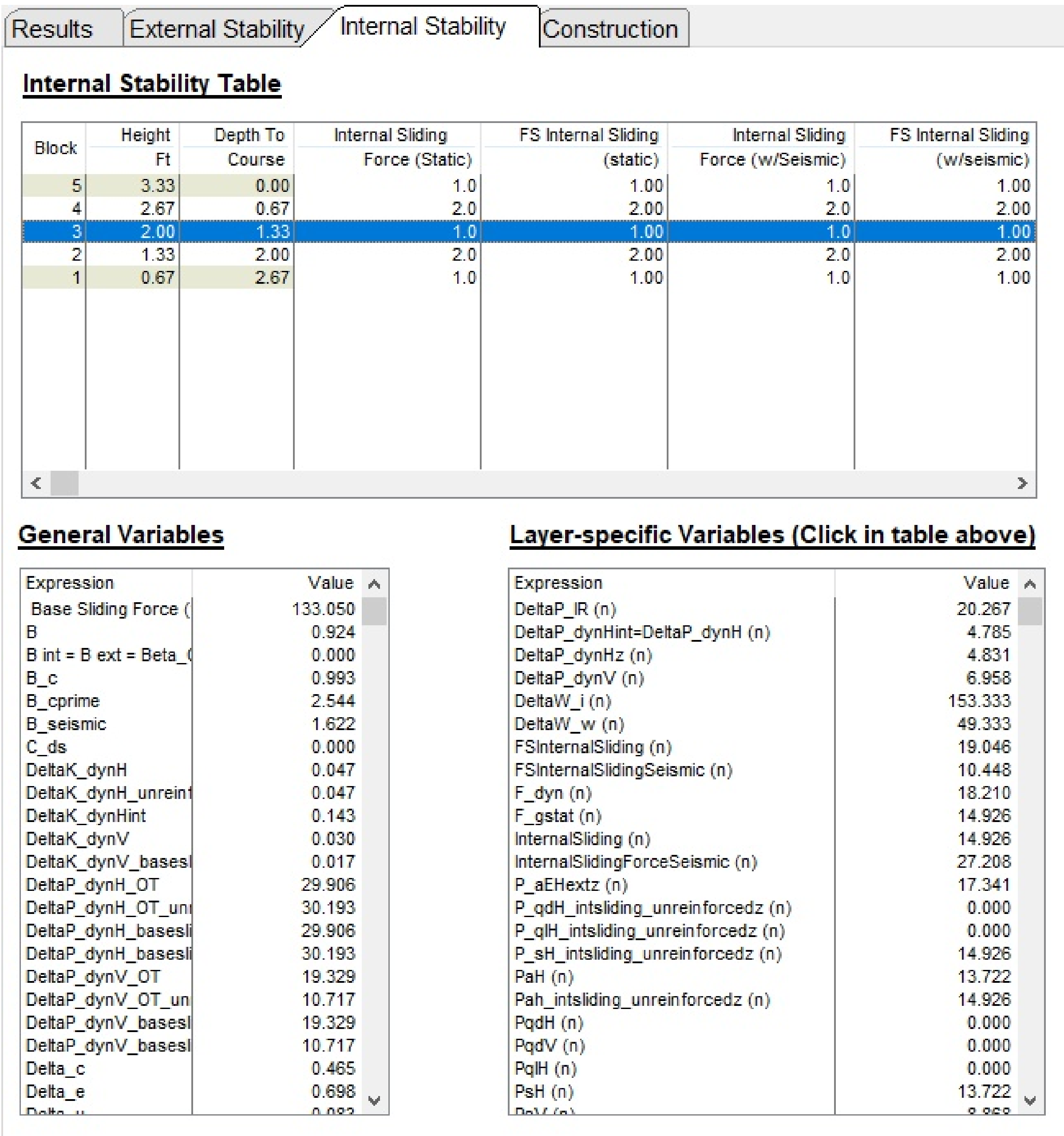
External Stability Tab

Displays overturning and sliding factors of safety as well as bearing pressure results.

Also reports eccentricity of vertical force and effective base width.

5.8.4 Internal Stability Tab (for Gravity Segmental Retaining Walls)

Internal Stability Tab (for Gravity Segmental Retaining Walls)



Block	Height Ft	Depth To Course	Internal Sliding Force (Static)	FS Internal Sliding (static)	Internal Sliding Force (w/Seismic)	FS Internal Sliding (w/seismic)
5	3.33	0.00	1.0	1.00	1.0	1.00
4	2.67	0.67	2.0	2.00	2.0	2.00
3	2.00	1.33	1.0	1.00	1.0	1.00
2	1.33	2.00	2.0	2.00	2.0	2.00
1	0.67	2.67	1.0	1.00	1.0	1.00

General Variables

Expression	Value
Base Sliding Force (	133.050
B	0.924
B int = B ext = Beta_(	0.000
B_c	0.993
B_cprime	2.544
B_seismic	1.622
C_ds	0.000
DeltaK_dynH	0.047
DeltaK_dynH_unreinf	0.047
DeltaK_dynHint	0.143
DeltaK_dynV	0.030
DeltaK_dynV_basesl	0.017
DeltaP_dynH_OT	29.906
DeltaP_dynH_OT_unr	30.193
DeltaP_dynH_basesli	29.906
DeltaP_dynH_basesli	30.193
DeltaP_dynV_OT	19.329
DeltaP_dynV_OT_un	10.717
DeltaP_dynV_basesl	19.329
DeltaP_dynV_basesl	10.717
Delta_c	0.465
Delta_e	0.698

Layer-specific Variables (Click in table above)

Expression	Value
DeltaP_IR (n)	20.267
DeltaP_dynHint=DeltaP_dynH (n)	4.785
DeltaP_dynHz (n)	4.831
DeltaP_dynV (n)	6.958
DeltaW_i (n)	153.333
DeltaW_w (n)	49.333
FSInternalSliding (n)	19.046
FSInternalSlidingSeismic (n)	10.448
F_dyn (n)	18.210
F_gstat (n)	14.926
InternalSliding (n)	14.926
InternalSlidingForceSeismic (n)	27.208
P_aEHextz (n)	17.341
P_qdH_intsliding_unreinforcedz (n)	0.000
P_qlH_intsliding_unreinforcedz (n)	0.000
P_sH_intsliding_unreinforcedz (n)	14.926
PaH (n)	13.722
Pah_intsliding_unreinforcedz (n)	14.926
PqdH (n)	0.000
PqdV (n)	0.000
PqlH (n)	0.000
PsH (n)	13.722

Internal Stability Tab

Displays internal stability table:

Block: Displays course numbers.

Height, ft: Displays the height from the base to the elevation of the top of each course.

Depth to Course: Displays the distance from the top of the wall to the top of each course.

Internal Sliding Force (static): The driving force at each course from static loading tending to cause the soil mass above to slide sideways.

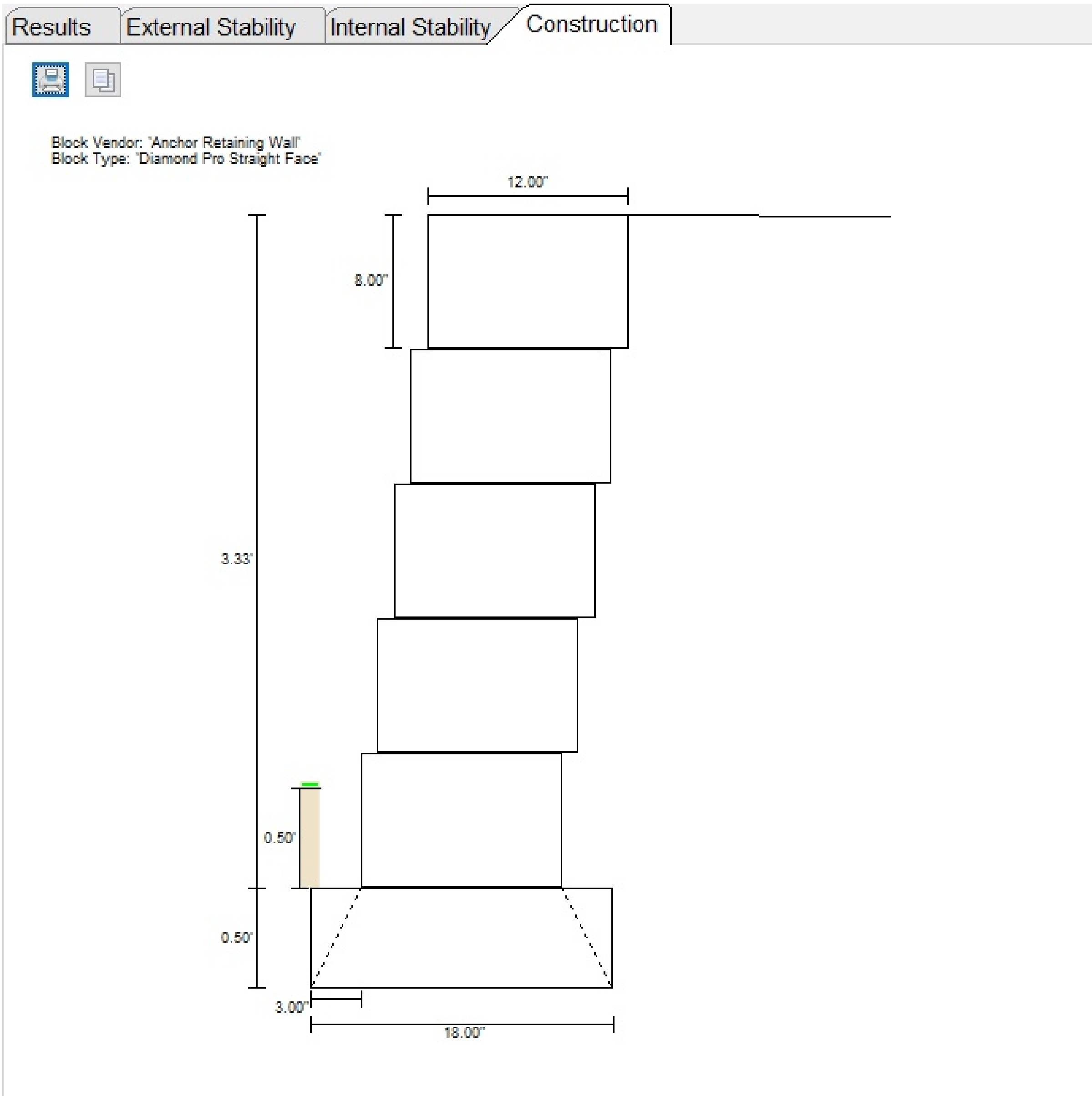
FS Internal Sliding (static): Internal sliding resistance / Static internal sliding force

Internal Sliding Force (w/ seismic): The driving force at each course from loading including seismic tending to cause the soil mass above to slide sideways.

FS Internal Sliding (w/ seismic): Internal sliding resistance / Internal sliding force (w/ seismic)

5.8.5 Construction Tab (for Gravity Segmental Retaining Walls)

Construction Tab (for Gravity Segmental Retaining Walls)



Construction Tab

Displays schematic drawing of wall.

5.9 Methodology / Analysis & Design Assumptions

Methodology / Analysis & Design Assumptions

References used for the development of this program are listed in Appendix E.

Surcharge can be composed of either dead load, live load, or both.

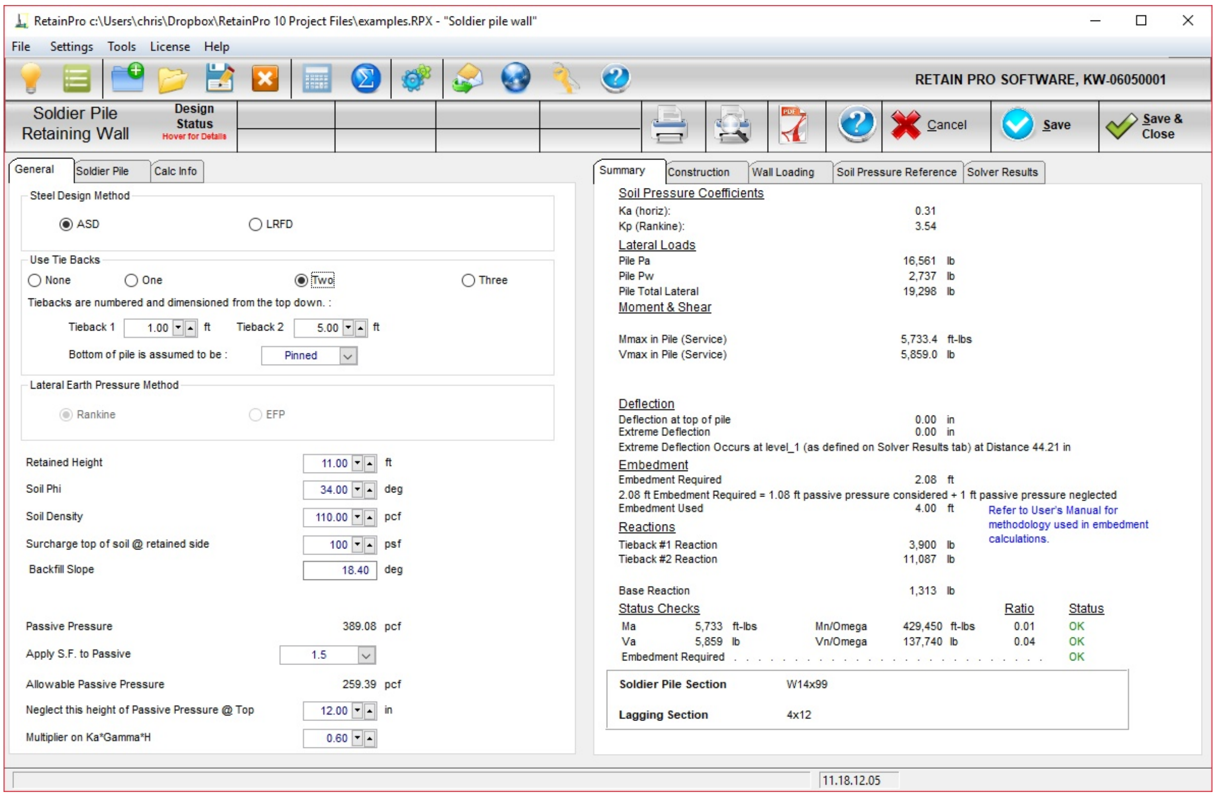
The design of segmental retaining walls generally follows the guidelines in *Design of Segmental Retaining Walls, 3rd Edition* published by the National Concrete Masonry Association (NCMA). Some assumptions have been made to simplify the program (as stated in the program), yet cover most construction practices and design requirements.

Part VI

6 Soldier Pile Retaining Wall

Soldier Pile Retaining Wall

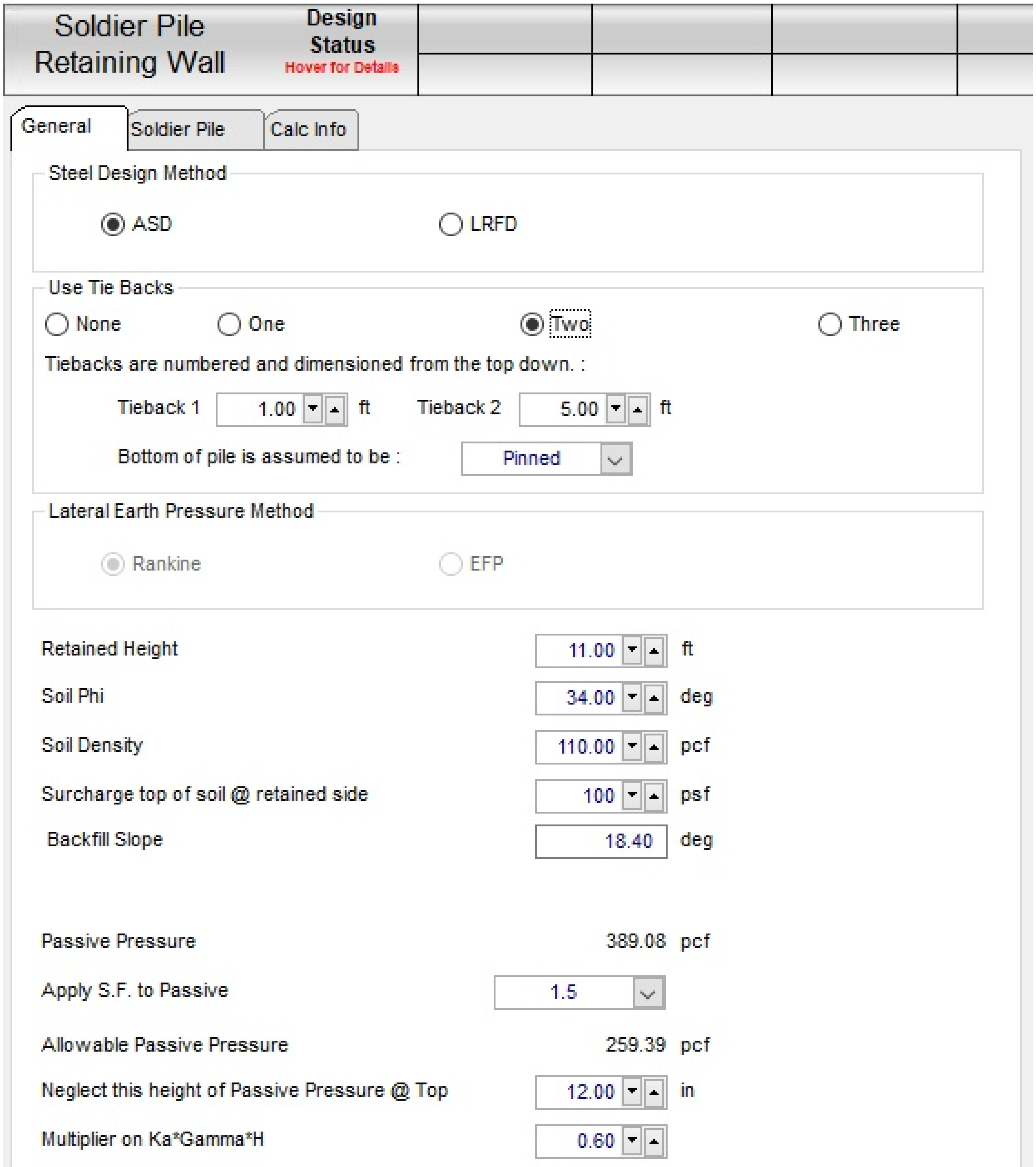
Soldier pile retaining walls, also called soldier beam walls, are generally used at construction sites for temporary shoring. Steel piles are driven into the ground, or placed in drilled holes filled with lean concrete, at a spacing such that lagging can be placed between the piles, and the excavation can proceed down to the level of the finished grade on the low side. The stability of a soldier pile retaining wall depends upon the active earth pressure being resisted by passive pressure on the embedded section of the pile. Pile spacing is typically 6 – 10 feet on center.



This module is suitable for cantilevered soldier piles (no tie-backs) or soldier piles with tie-backs.

6.1 General Tab

General Tab



Steel Design Method: Select ASD or LRFD methods for design of steel pile

Use Tie-Backs: Select none, one, two, or three. If any tie-backs are used, they are located by their distance from the top of the pile.

Bottom of pile is assumed to be: This is a conditional input. It is only available when tie-backs **are** used, which triggers a stiffness analysis using Structural Engineering Library's 2D Frame program in the background. The pile is modeled in segments from spanning between tie-backs. The bottom segment spans from the lowest tie-back to the bottom of the embedment depth. This setting controls whether that lowest support is considered fixed or pinned with regard to rotation.

Lateral Earth Pressure Method: This is a conditional input. It is only available when tie-backs are **not** used. When it is available, it allows the use of Rankine Active Pressure or Equivalent Fluid Pressure methods. When tie-backs are used, the pressure is applied as described on the Soil Pressure Reference tab.

Retained Height, ft: Distance between the final excavated grade and the retained height at the top grade.

Soil Phi, degrees: Angle of internal friction of the retained material, usually obtained from the geotechnical engineer.

Soil Density, pcf: Density of the retained soil, usually 100 to 130 pcf.

Surcharge top of soil at retained side, psf: Surcharge on upper grade such as for equipment, materials, or contingencies.

Backfill Slope, degrees: Slope of the backfill measured in degrees from horizontal.

Passive Pressure, psf/ft: Passive pressure in pcf. When using Rankine active soil pressure method, passive pressure is calculated as (1/Ka)*(soil density). When using EFP, the passive pressure is a user input.

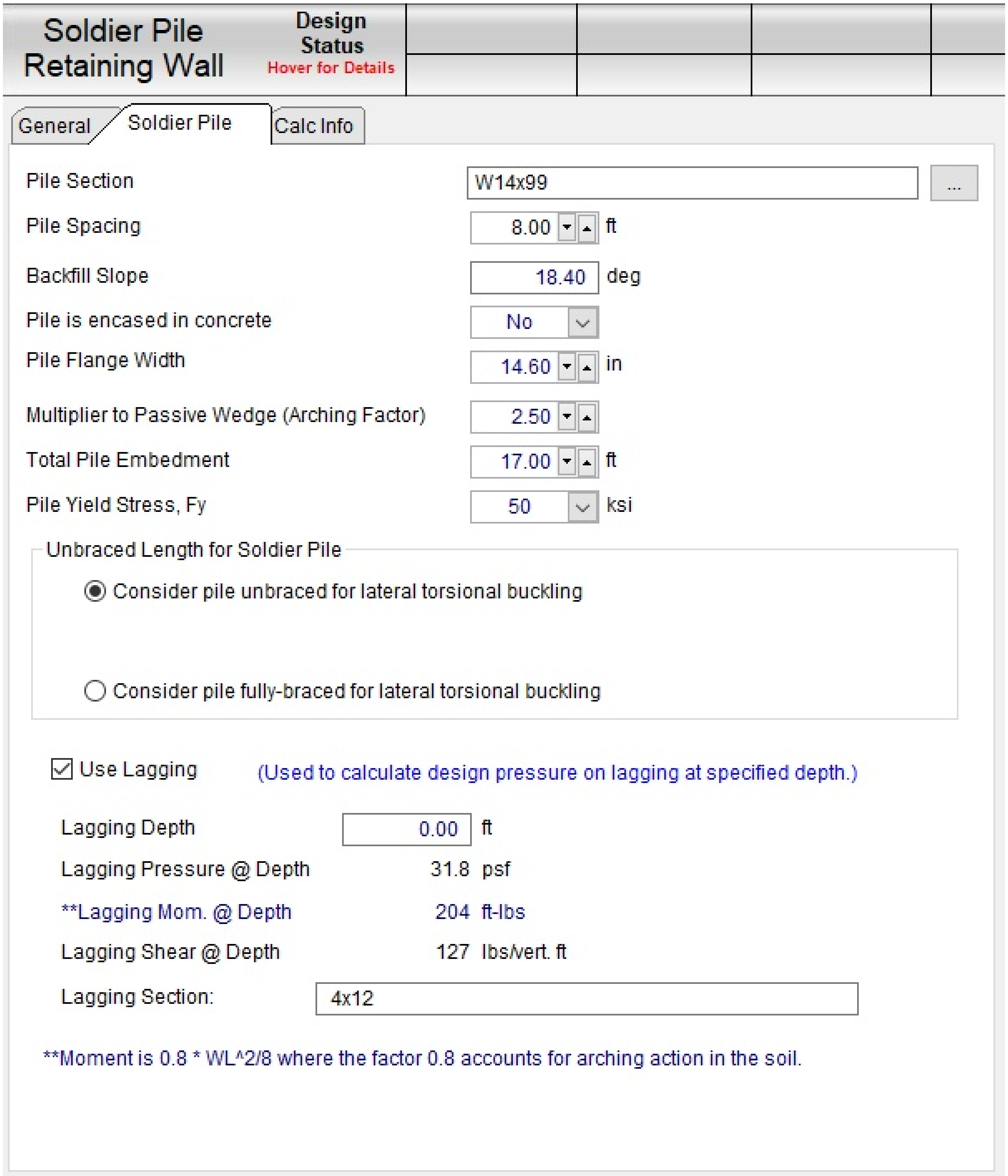
Apply S.F. to Passive Pressure: Safety factor that will be applied to the above passive pressure, typically 1.5.

Neglect this height of Passive Pressure @ Top: Allows a specified height of passive pressure to be ignored for resistance, such as if the soil was likely to be frost disturbed or otherwise unsuitable to resist lateral pressure.

Multiplier on Ka*Gamma*H: This is a conditional input. It is only available when tie-backs **are** used. The Soil Pressure Reference tab shows how the soil pressure distribution is developed. This factor allows the user to fine tune the pressure value.

6.2 Soldier Pile Tab

Soldier Pile Tab



Pile Section: Opens the Steel Section Database, allowing the selection of common pile sections.

Pile Spacing, ft: Center to center spacing of piles, typically 6 ft to 10 ft.

Pile is encased in concrete: Select whether the steel pile is driven into the soil or placed into a drilled hole and encased in lean concrete.

Pile Flange Width / Diameter of Encasement, in: If the pile is driven, enter the flange width. If the pile is set in lean concrete in a drilled hole, enter the hole diameter.

Multiplier to Passive Wedge: This is an arching factor. It takes the form of a multiplier from 1.0 to 3.0 to be applied to the pile flange width or drilled hole diameter due to wedging action and is usually provided by the geotechnical engineer.

Total Pile Embedment, ft: Actual embedment, usually rounded from the required embedment reported below.

Pile Yield Stress, Fy: Yield stress of the selected pile section.

Unbraced Length for Soldier Pile: Allows the user to specify the unbraced length for steel design purposes. This is a conditional input.

<u>If the pile is **not** tied back, the user can select:</u>

- Consider pile unbraced for lateral torsional buckling
- Consider pile fully-braced for lateral torsional buckling

<u>If the pile **is** tied back, the user can select:</u>

- Consider pile unbraced for lateral torsional buckling
- Consider pile to be braced at tieback locations
- Consider pile fully-braced for lateral torsional buckling

Use Lagging: Check this box if lagging is to be considered between piles.

Lagging Depth, ft: Depth below grade at which lagging pressure is to be calculated based on the active soil pressure.

Lagging Pressure @ Depth, psf: Pressure used in the design of horizontal wood lagging between piles.

Lagging Moment @ Depth, ft-lbs: Moment computed assuming arching action and using moment = 0.8 * $wl^2/8$.

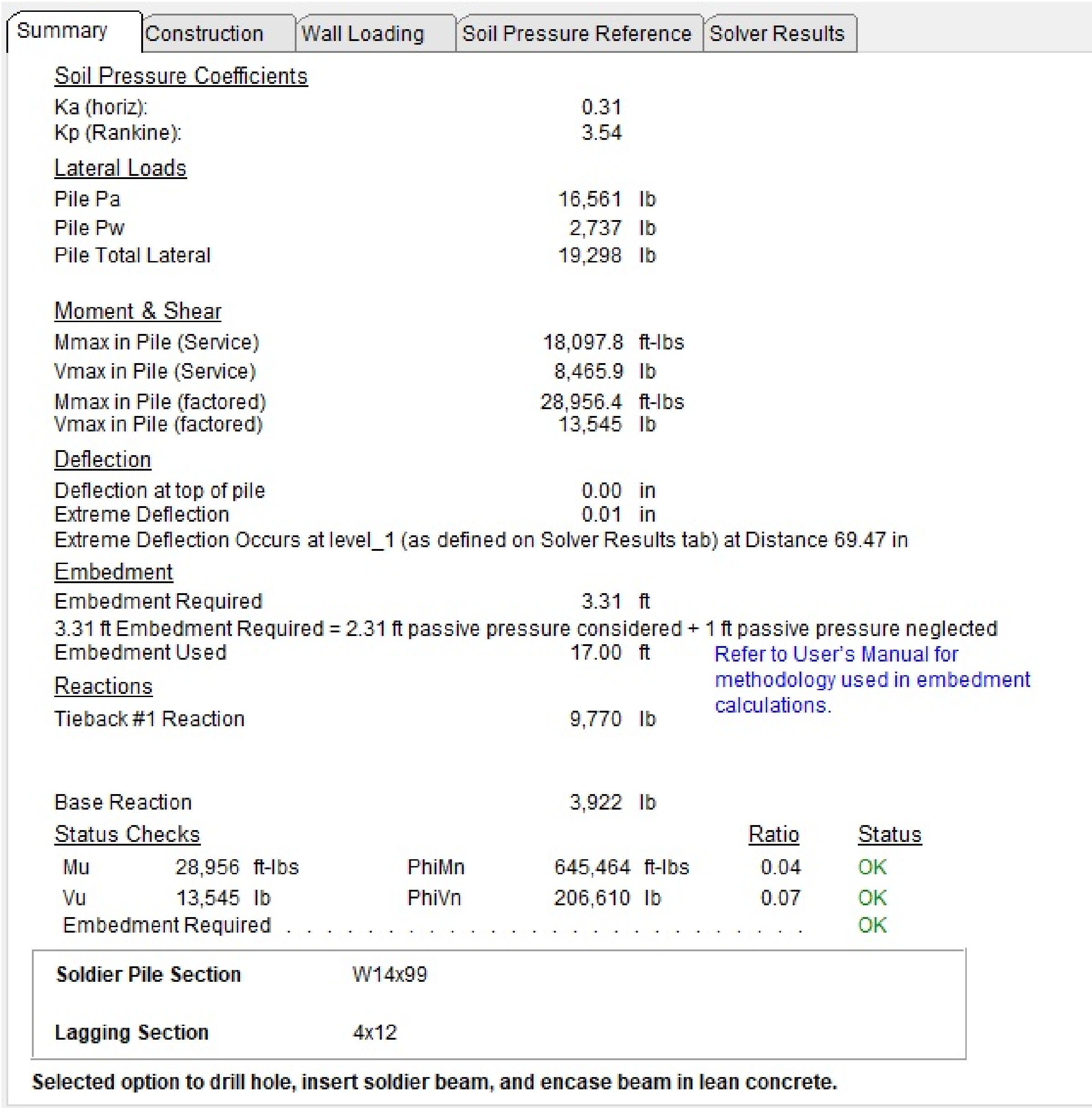
Lagging Shear @ Depth, lb/vertical ft: Shear computed using wl/2 where w is the Lagging Pressure @ Depth determined above.

Lagging selection: Wood lagging selection, such as 4 in x 12 in. No design is performed based on this entry, but it is printed in the calculation report for documentation purposes.

6.3 Results Tabs

6.3.1 Summary Tab

Summary Tab



Soil Pressure Coefficients:

Ka (horiz) and Kp (Rankine) are computed automatically when using the Rankine method. Kp (Rankine) is calculated as 1/Ka for a backfill slope of zero.

Lateral Loads:

Pile Pa, lbs: Total lateral force due to earth pressure.

Pile Pw, lbs: Total lateral force due to surcharge if applicable.

Pile Total lateral, lbs: Sum of Pa + Pw

Moments & Shears:

Depth to Max M, ft: Distance below lower grade to point of maximum moment in the pile.

Mmax in Pile (Service), ft-lbs: Maximum service level moment in the pile.

Vmax in Pile (Service), ft-lbs: Maximum service level shear in the pile.

Mmax in Pile (Factored), ft-lbs: Maximum factored level moment in the pile. A factor of 1.6 is used.

Vmax in Pile (Factored), ft-lbs: Maximum factored level shear in the pile. A factor of 1.6 is used.

Deflection: This is a conditional result.

If the pile has **no** tie-backs, the result will report the deflection at the top of the pile.

If the pile **has** tie-backs, the result will report the deflection at the top of the pile, as well as the extreme deflection and the location where the extreme deflection was found to occur. Refer to the Solver Results tab for more information on how to locate the point of extreme deflection.

Embedment:

Reports the required pile embedment based upon allowable passive pressure, the specified safety factor and the applied active pressure. The result is further itemized into the length of embedment that is considered effective for passive resistance and the portion that is neglected (if any). Finally, the results report the embedment used for documentation purposes.

Reactions: This is a conditional result.

If the pile has **no** tie-backs, this area will be blank.

If the pile **has** tie-backs, the result will report the tie-back reactions and the base reaction as determined by the stiffness analysis.

Status Checks:

Reports Mu (or Ma), phiMn (or Mn/Omega), the ratio, and an OK/NG status.

Reports Vu (or (Va), phiVn (or Vn/Omega), the ratio, and an OK/NG status.

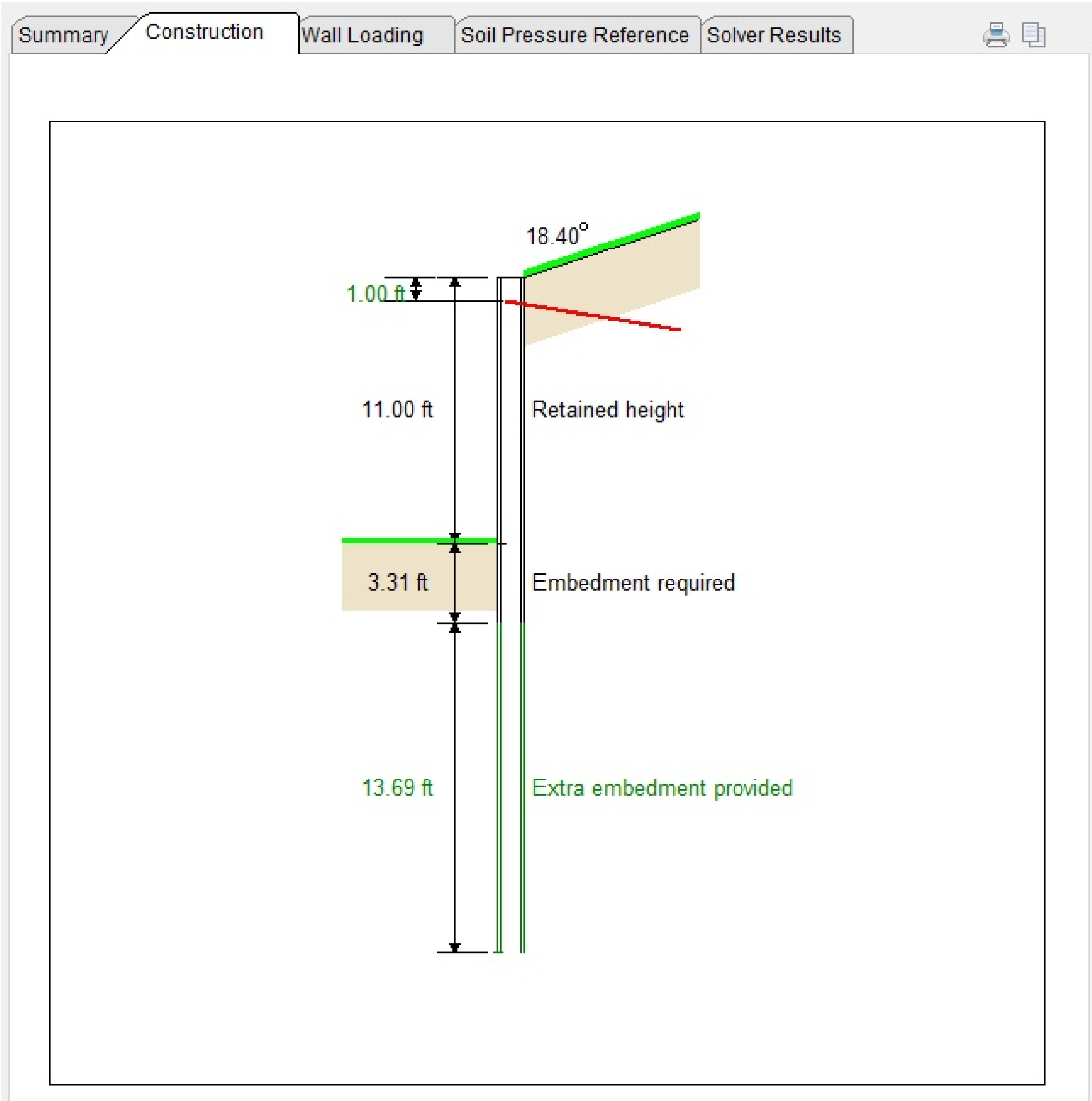
Reports an OK/NG status on the Embedment.

Soldier Pile Section documents the selected section for the pile.

Lagging Section documents the selected section for the lagging.

6.3.2 Construction Tab

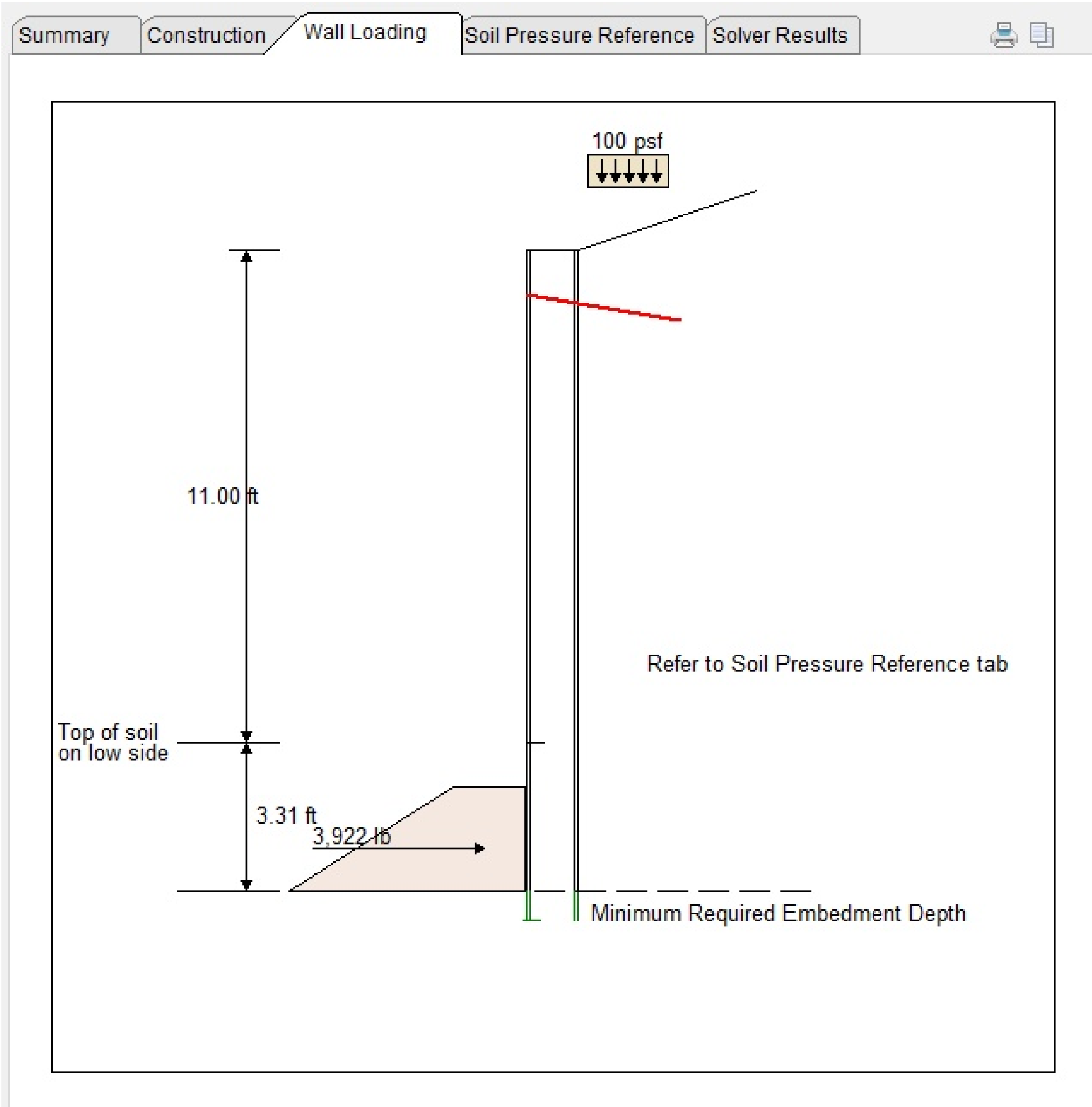
Construction Tab



Displays the soldier pile, the retained soil, tie-backs (if any), and critical dimensions.

6.3.3 Wall Loading Tab

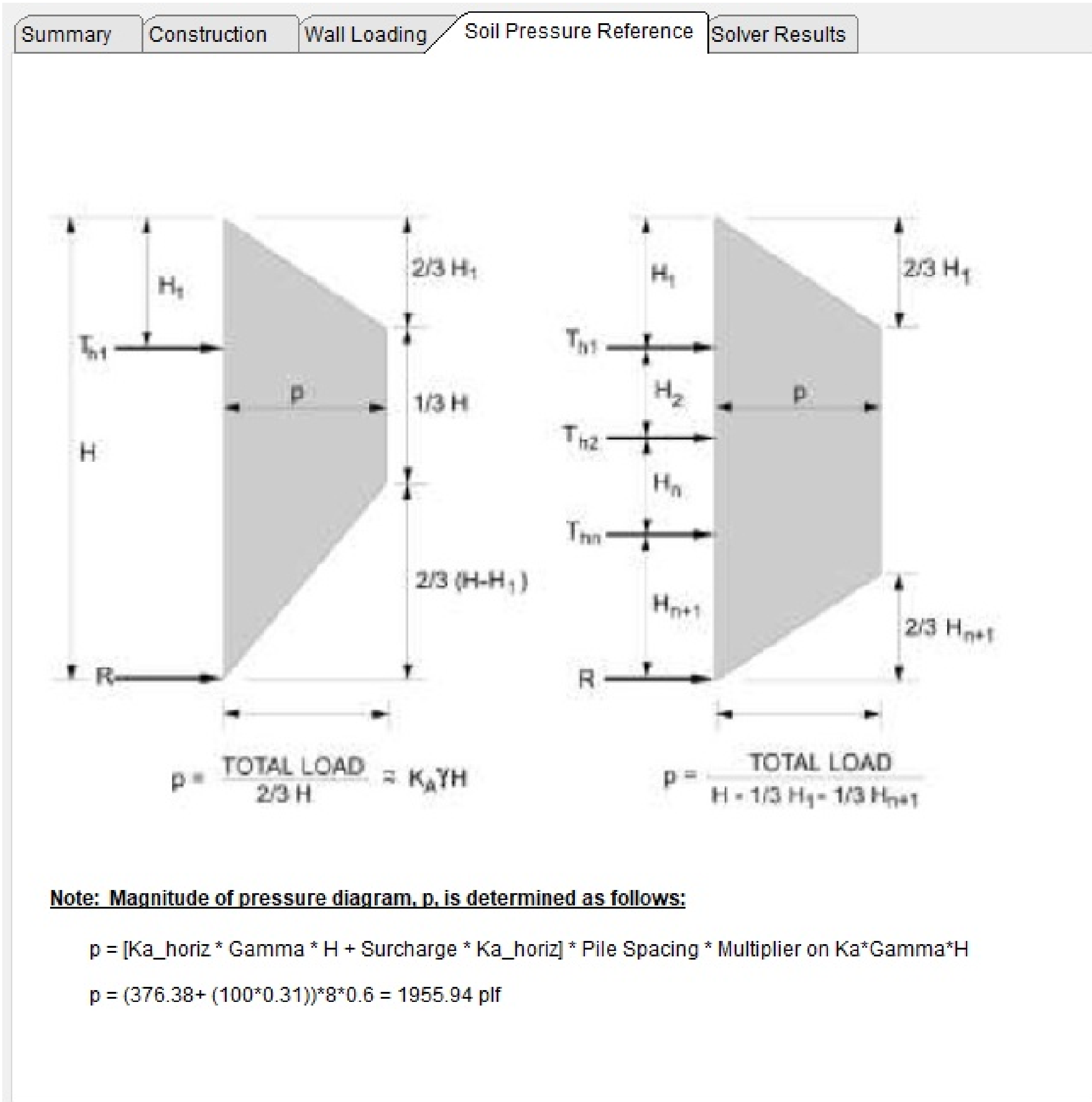
Wall Loading Tab



Displays the soldier pile, the retained soil, tie-backs (if any), surcharge load (if any), and passive pressure diagram.

6.3.4 Soil Pressure Reference

Soil Pressure Reference Tab



Displays the loading diagram that is applied to the 2D Frame analysis model, as well as the derivation of the pressure values.

H: Retained height

Th1...Thn: Tie-back reactions

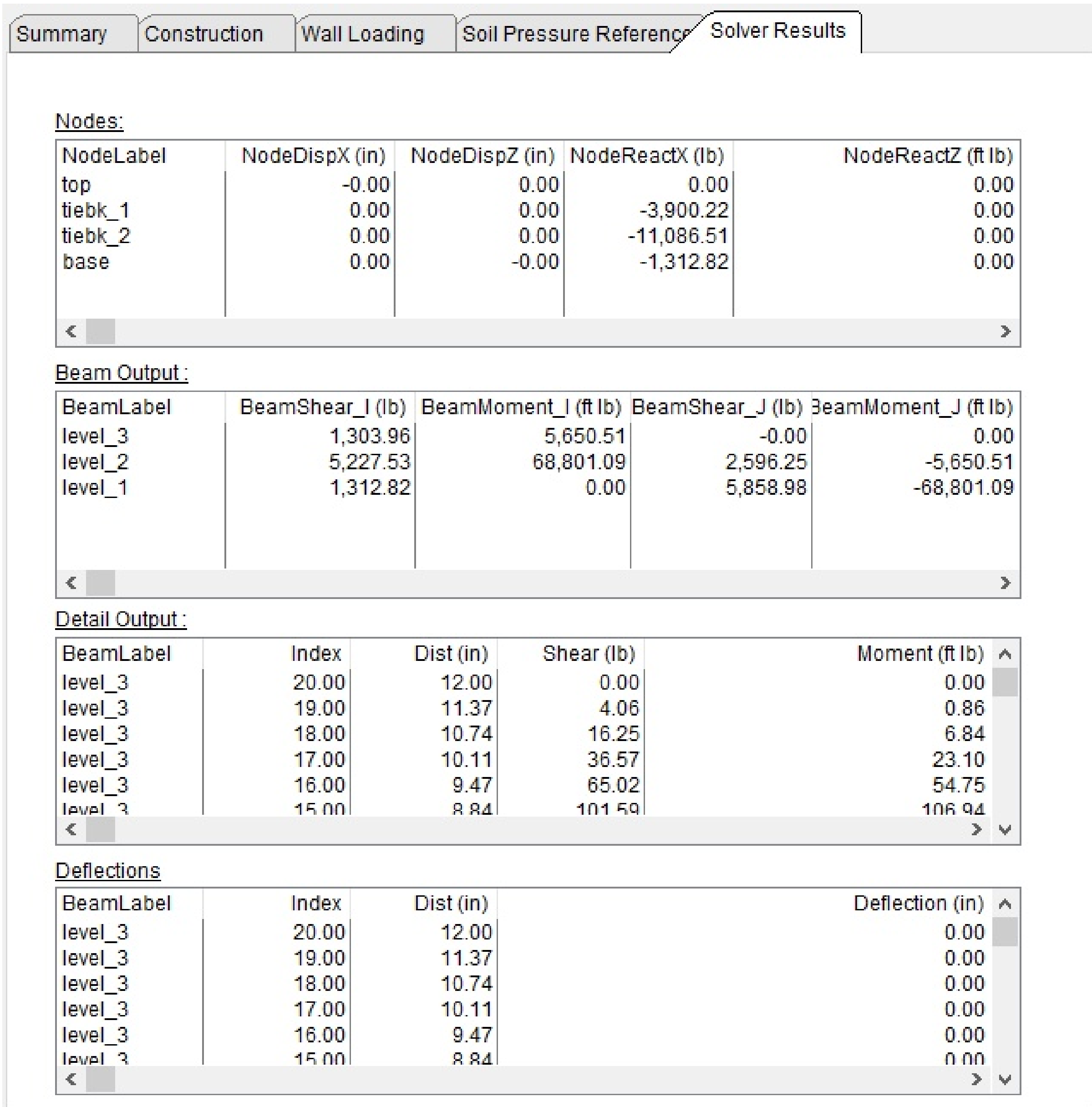
H1...Hn: Dimensions used to locate tiebacks

R: Lateral reaction at base

p: Maximum pressure intensity as determined by [Ka_horiz * Gamma * H + Surcharge * Ka_horiz] * Pile Spacing * Multiplier on Ka * Gamma * H

6.3.5 Solver Results

Solver Results Tab



Summary | Construction | Wall Loading | Soil Pressure Reference | Solver Results

Nodes:

NodeLabel	NodeDispX (in)	NodeDispZ (in)	NodeReactX (lb)	NodeReactZ (ft lb)
top	-0.00	0.00	0.00	0.00
tiebk_1	0.00	0.00	-3,900.22	0.00
tiebk_2	0.00	0.00	-11,086.51	0.00
base	0.00	-0.00	-1,312.82	0.00

Beam Output :

BeamLabel	BeamShear_I (lb)	BeamMoment_I (ft lb)	BeamShear_J (lb)	BeamMoment_J (ft lb)
level_3	1,303.96	5,650.51	-0.00	0.00
level_2	5,227.53	68,801.09	2,596.25	-5,650.51
level_1	1,312.82	0.00	5,858.98	-68,801.09

Detail Output :

BeamLabel	Index	Dist (in)	Shear (lb)	Moment (ft lb)
level_3	20.00	12.00	0.00	0.00
level_3	19.00	11.37	4.06	0.86
level_3	18.00	10.74	16.25	6.84
level_3	17.00	10.11	36.57	23.10
level_3	16.00	9.47	65.02	54.75
level_3	15.00	8.84	101.59	106.94

Deflections

BeamLabel	Index	Dist (in)	Deflection (in)
level_3	20.00	12.00	0.00
level_3	19.00	11.37	0.00
level_3	18.00	10.74	0.00
level_3	17.00	10.11	0.00
level_3	16.00	9.47	0.00
level_3	15.00	8.84	0.00

Displays the results from the 2D Frame analysis model.

Nodes: Displays the node list as well as displacements and reactions

Beam Output: Displays list of beam segments with shears and moments

Detail Output: Displays list of beam segments with shears and moments at small increments along the height of the pile

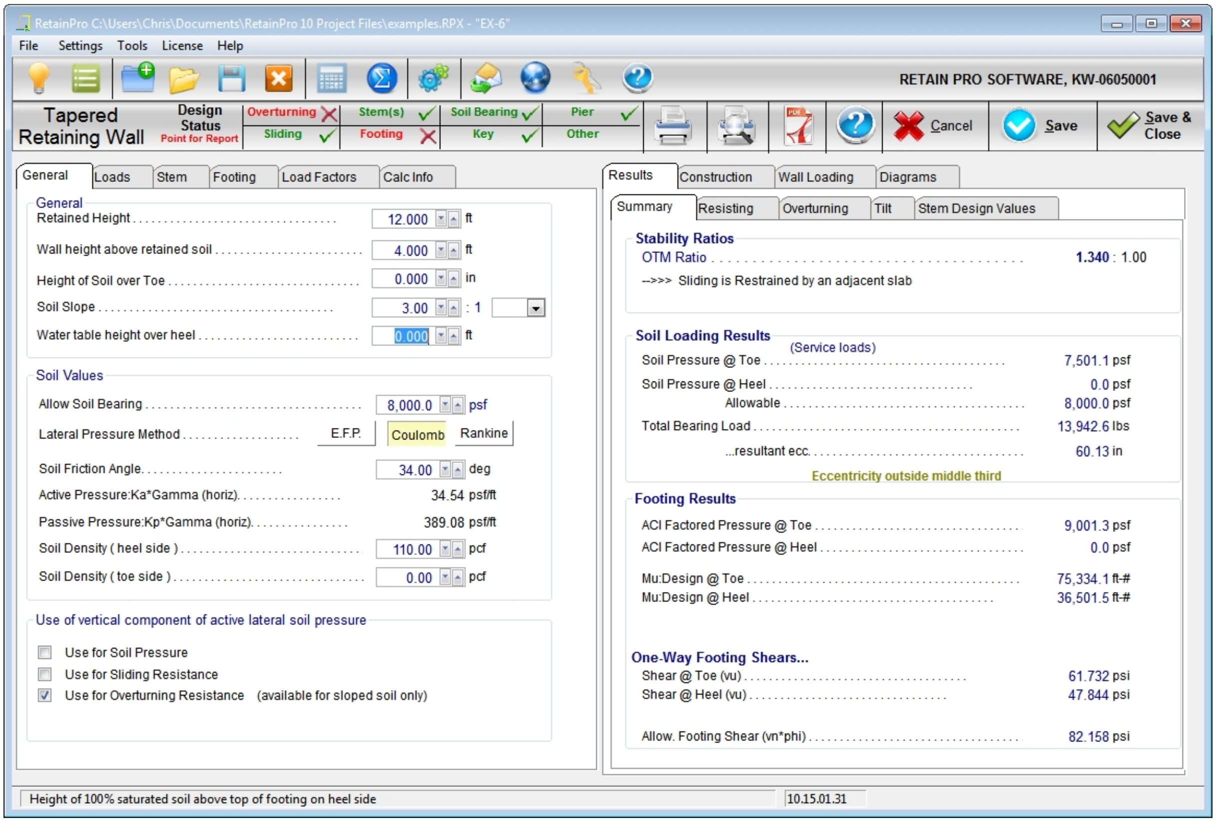
Deflections: Displays list of beam segments with deflection values at small increments along the height of the pile

Part VII

7 Tapered Stem Retaining Wall

Tapered Stem Retaining Wall

Tapered Stem Retaining Walls are cantilevered retaining walls where the soil face is battered to achieve a variable thickness from the base of the stem to the top of the stem.



The input parameters are significantly the same as those in the Cantilevered Retaining Wall. Refer to that section for their descriptions.

7.1 Methodology / Analysis & Design Assumptions

Methodology / Analysis & Design Assumptions

References used for the development of this program are listed in Appendix E.

Stem design material is limited to concrete, because it is impractical to construct a tapered wall with concrete masonry units. Design strength of concrete may be specified.

Conventional "heel" and "toe" terminology is used, whereby the "heel" side of the wall supports the retained earth. In this program, the "heel" distance is measured from the front face of the stem.

Concrete design for stem and footing is based upon ultimate strength design (SD) using factored loads. Factors for various building codes will be displayed on the Load Factors page, and may be edited. Since they are editable, be sure to check them before starting a design since you may have changed them.

Where stem thickness varies, it is assumed that the front face (toe side) of the stem is flush, and the change in thickness occurs on the heel side.

A geotechnical engineer will typically have determined design criteria (equivalent fluid pressure, allowable soil bearing pressure, sliding coefficient, etc.). If this is not the case, you can enter the angle of internal friction for the soil, and the program will compute the corresponding active pressure, using the Coulomb formulas based upon the soil density and backfill slope you have specified. If the Coulomb method is chosen, passive pressure will be based upon the Rankine Formula, assuming a level toe-side backfill.

Global stability is not checked.

Horizontal temperature/shrinkage reinforcing is at the discretion of the designer and is not computed by the program. For horizontal temperature and shrinkage reinforcing for various stems see Appendix A.

Axial loads may be applied to the top of the stem but it is recommended that they do not exceed about 3,000 lbs to avoid reversal of heel bending moment. Slenderness interaction reductions for cantilevered walls are not calculated since h/t ratios are typically less than about 12. Only "positive" eccentricities from the centerline of the top stem are accepted (i.e. toward the toe), since negative eccentricity could lead to unconservative results.

Excessively high axial loads are not anticipated by the program and should not be applied if they would cause tension in the bottom of the footing heel – the program assumes typical retaining wall conditions where the heel moment causes tension at the top of the footing. If a design requires a very high axial load, say, over 3 kips/lf, it is suggested to use footing design software or hand calculations.

Critical section for bending in the footing is at the face of the concrete stem. For shear, the critical section is a distance "d" from the face of the stem toward the toe, and at the face of the stem for the heel. The program does not calculate toe or heel bar development lengths inward from the face of the stem (where the moment is maximum). When selecting and detailing the arrangement of toe and heel bars this should be considered. Refer to Appendix B for development lengths in concrete, which can be adjusted for the stress level.

The program calculates the bending in the key and determines whether reinforcing is required. For determining section modulus, 3" is deducted from the key width per ACI recommendation. If reinforcing is required, a message will appear. You can then change the key dimensions until the message disappears, or use the rebar suggestions displayed. The key moment and shear is produced by the passive resisting pressure acting against the key.

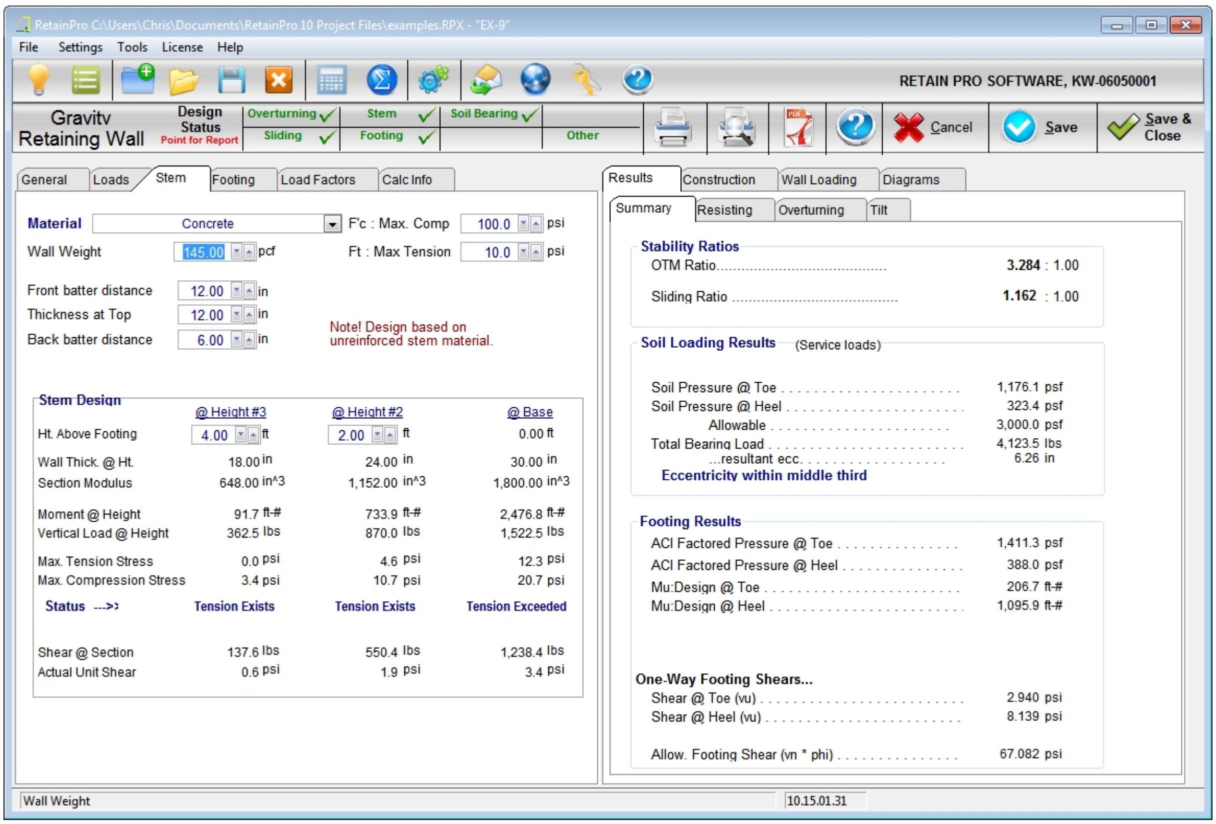
Slab restraint at the base can be specified on the Footing > Key Design & Sliding Options tab. The program only allows this restraint to occur at the top of the footing – not higher.

Part VIII

8 Gravity Retaining Wall

Gravity Retaining Wall

Gravity Retaining Walls are cantilevered retaining walls where both faces can be battered battered to achieve a variable thickness from the base of the stem to the top of the stem, and where stability is generally accomplished by the magnitude of the wall weight itself, rather than by long extensions on the toe and heel of the footing.



The input parameters are significantly the same as those in the Cantilevered Retaining Wall. Refer to that section for their descriptions.

8.1 Methodology / Analysis & Design Assumptions

Methodology / Analysis & Design Assumptions

References used for the development of this program are listed in Appendix E.

Stem design material is limited to concrete or rubble masonry. Allowable tensile and compressive stresses may be specified. Stem stresses are compared to specified allowable values to evaluate the adequacy of the stem.

Conventional "heel" and "toe" terminology is used, whereby the "heel" side of the wall supports the retained earth. In this program, the "heel" distance is measured from the front face of the stem.

A geotechnical engineer will typically have determined design criteria (equivalent fluid pressure, allowable soil bearing pressure, sliding coefficient, etc.). If this is not the case, you can enter the angle of internal friction for the soil, and the program will compute the corresponding active pressure, using the Coulomb formulas based upon the soil density and backfill slope you have specified. If the Coulomb method is chosen, passive pressure will be based upon the Rankine Formula, assuming a level toe-side backfill.

Global stability is not checked.

Horizontal temperature/shrinkage reinforcing is at the discretion of the designer and is not computed by the program. For horizontal temperature and shrinkage reinforcing for various stems see Appendix A.

Axial loads may be applied to the top of the stem but it is recommended that they do not exceed about 3,000 lbs to avoid reversal of heel bending moment. Slenderness interaction reductions for cantilevered walls are not calculated since h/t ratios are typically less than about 12. Only "positive" eccentricities from the centerline of the top stem are accepted (i.e. toward the toe), since negative eccentricity could lead to unconservative results.

Excessively high axial loads are not anticipated by the program and should not be applied if they would cause tension in the bottom of the footing heel – the program assumes typical retaining wall conditions where the heel moment causes tension at the top of the footing. If a design requires a very high axial load, say, over 3 kips/lf, it is suggested to use footing design software or hand calculations.

Critical section for bending in the footing is at the face of the concrete stem. For shear, the critical section is a distance "d" from the face of the stem toward the toe, and at the face of the stem for the heel. The program does not calculate toe or heel bar development lengths inward from the face of the stem (where the moment is maximum). When selecting and detailing the arrangement of toe and heel bars this should be considered. Refer to Appendix B for development lengths in concrete, which can be adjusted for the stress level.

The program calculates the bending in the key and determines whether reinforcing is required. For determining section modulus, 3" is deducted from the key width per ACI recommendation. If reinforcing is required, a message will appear. You can then change the key dimensions until the message disappears, or use the rebar suggestions displayed. The key moment and shear is produced by the passive resisting pressure acting against the key.

Slab restraint at the base can be specified on the Footing > Key Design & Sliding Options tab. The program only allows this restraint to occur at the top of the footing – not higher.

Part IX

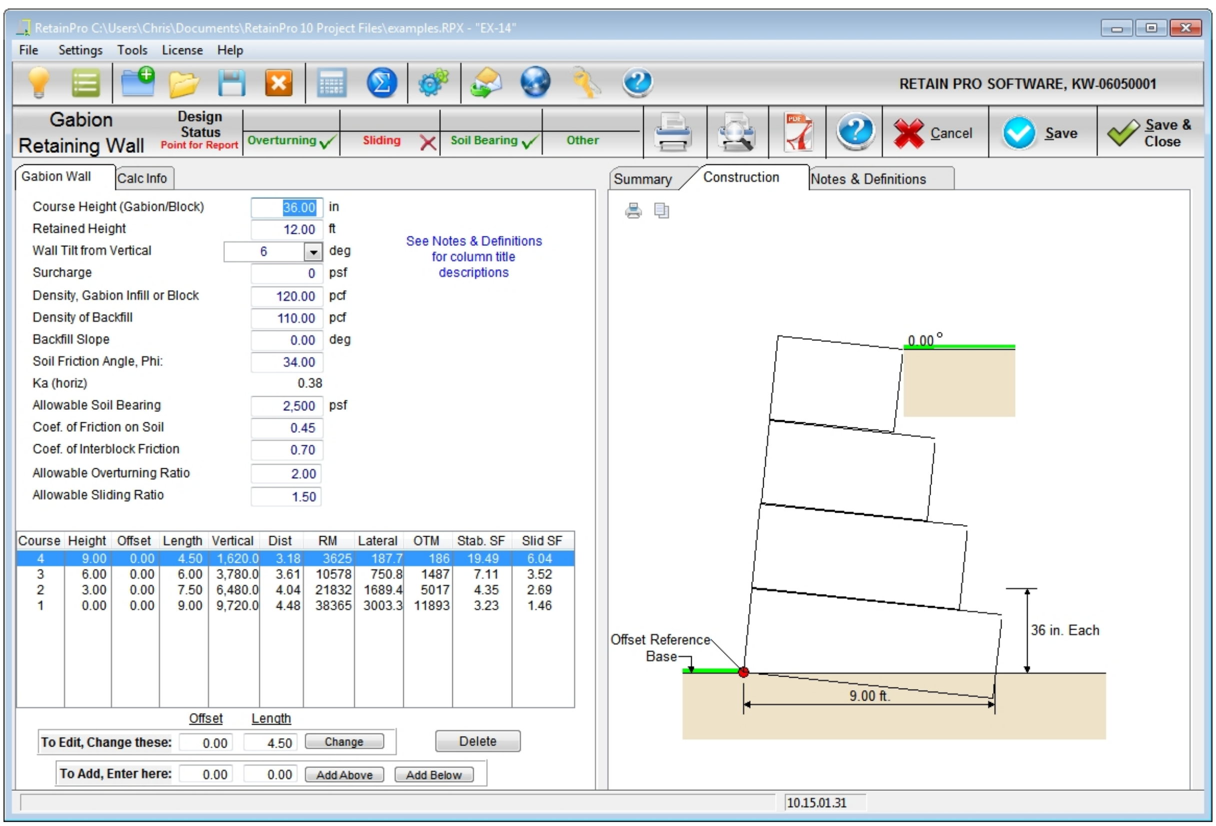
9 Gabion Wall

Gabion Wall

A gabion wall is a gravity wall constructed using prefabricated steel wire cages filled with rock. The cages are often 3 ft on a side and are infilled with stone as specified by the designer. In lieu of rock filled gabion cages, large precast concrete blocks may be used.

This program assumes all cages or blocks to be of uniform size and infill density. They can either be assembled vertically or tilted backward by selecting either 3° or 6° tilt. Maximum allowed height is 18 ft. A rule of thumb for the length of the bottom course is 75% of the retained height. The retained height is assumed to be the same height as the wall. The Coulomb equation is used for determining lateral earth pressure. As of July 2016 the Gabion Wall module uses the following values in the Coulomb equation: Angle of soil face of wall is equal to 90 degrees plus the user-specified wall tilt value, and the soil-wall friction angle is equal to (2/3) Phi.

This Gabion Wall program does not handle MSE (mechanically stabilized earth) walls, which use geogrids.



Notes:

1. All courses are of the same height and infill density.

2. If wall depth is uniform, consider using segmental retaining wall module with the gravity wall (no geogrids) option.
3. Concrete blocks may be used in lieu of gabion cages.
4. Offset of successive layers is limited to one-half course height. Earth side face flush.
5. Coulomb equation is used for active pressure. Wall friction angle is assumed zero.
6. If wall is battered, the effect can be modeled by introducing successive offsets (tan beta times course height).
7. This design is not valid for reinforced soils (Mechanically Stabilized Earth). Consider using Segmental Retaining Wall module instead.
8. Vendor specifications may apply.

Course Height (Gabion/Block), In: Height of the Gabion cages or block in inches. This is assumed uniform throughout.

Retained Height, ft: Retained height in ft. which is also assumed to be the top of the wall.

Wall Tilt from Vertical, deg: Select "None", 3°, or 6° backward tilt.

Surcharge, psf: Surcharge load if applicable.

Density, Gabion Infill or Block, pcf: Density of the infill or block. A rock infill is typically 120pcf and concrete block is typically 140pcf.

Density of Backfill, pcf: Density of the backfill material, typically provided by the geotechnical engineer.

Backfill Slope, deg: If applicable, enter the backfill slope in degrees.

Soil Friction Angle, Phi: Obtain this from the geotechnical engineer. 35° is typical.

Ka (horiz): Computed using the Coulomb equation with variables being phi, backfill slope and with wall/soil friction angle assumed to be 0°.

Allowable Soil Bearing, psf: Obtain this value from the geotechnical engineer.

Coef. of Friction on Soil: As determined by the geotechnical engineer. Typically 0.25-0.50.

Coef. of Interblock Friction: Coefficient of friction to resist sliding between cages or blocks. A value 0.70 is often used.

Overturning Ratio: Controlling ratio of the resisting moment divided by the overturning moment.

Sliding Ratio: Computed for each level and is the ratio of the sliding resistance (weight of courses above times coefficient of interblock friction) and the applied lateral force. If it is less than 1.5 it will appear in red.

Act. Soil Bearing Pressure, psf: Computed using conventional statics and appears in red if it exceeds the allowable cell bearing specified.

Table of course entries and values

Course: These are numbered in ascending order and cannot exceed 10.

Height: Measured from bottom of first (base) course.

Offset: Measured from front edge bottom course.

Length: Of cages or blocks in course.

Vertical: Accumulated vertical load from courses above.

Dist: Horizontal distance from front edge of bottom course to centroid of the referenced course.

RM: Resisting moment at referenced course.

Lateral: Accumulated lateral force from earth pressure and surcharge.

OTM: Accumulated overturning moment above referenced course.

Stab S.F.: RM / OTM

Sliding S.F.: Vertical * (Coef. Interblock friction) / Lateral.

Add, edit or delete courses using the buttons and input fields below the table. The first value entered will automatically be the bottom layer. To delete a course highlight it and click Delete.

9.1 Methodology / Analysis & Design Assumptions

Methodology / Analysis & Design Assumptions

References used for the development of this program are listed in Appendix E.

Part X

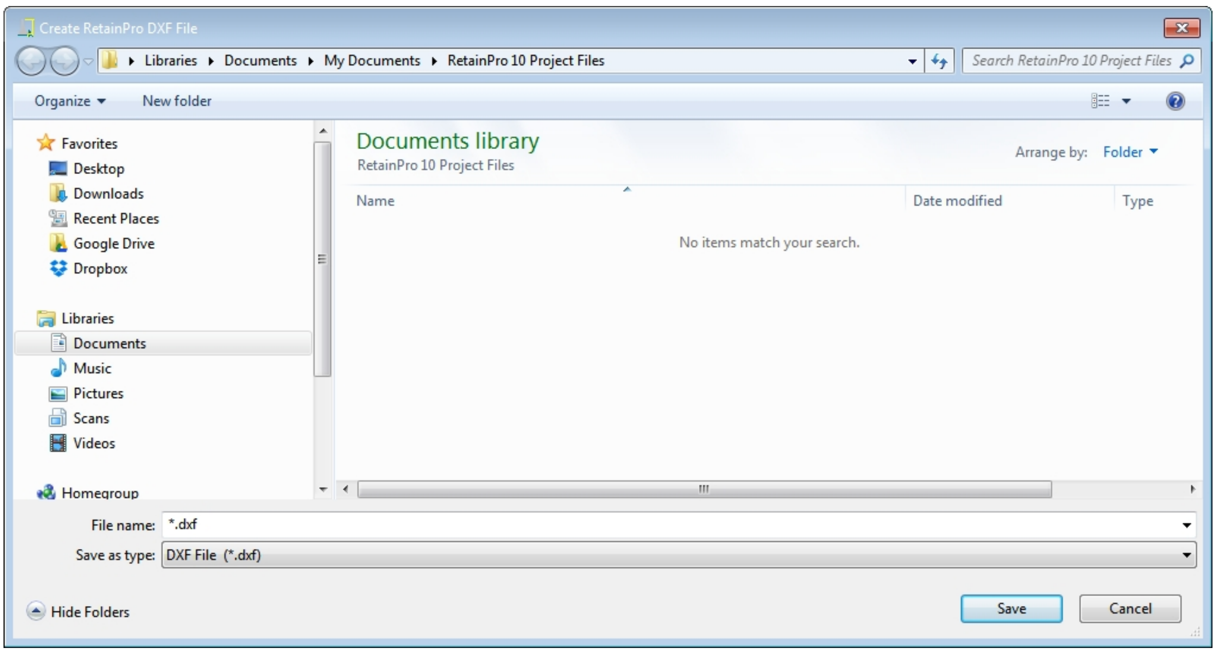
10 Creating DXF Files

Creating DXF Files

RetainPro can create a retaining wall construction drawing in DXF format to import into a CAD program.

The procedure to create a Drawing Exchange Format (DXF) file is as follows:

1. **Click File > Create DXF** in the menu bar.
2. Create RetainPro DXF File dialog appears:



3. Navigate to the folder where the DXF file is to be saved and click the **Save** button.

Part XI

11 Appendices

Appendix A - Table of Horizontal Temperature and Shrinkage Reinforcing
Appendix B - Development and Lap Lengths
Appendix C - Weights of Masonry Walls
Appendix D - Summary of Concrete & Masonry Design Formulas
Appendix E - References Used For The Development Of This Program
Appendix F - Rankine and Coulomb Formulas

11.1 Appendix A - Table of Horizontal Temperature and Shrinkage Reinforcing

Appendix A - Table of Horizontal Temperature and Shrinkage Reinforcing

Typical Horizontal Rebar Spacing for .0007 A_g Masonry and .002 A_g for concrete						
Mat'l	**Thick**	**#3**	**#4**	**#5**	**#6**	**#7**
Concrete	6	9	17	18	18	—
Concrete	7	8	14	18	18	—
Concrete	8	7	12	18	18	—
Concrete	9	6	11	17	18	—
Concrete	10	5.5	10	15	18	—
Concrete*	12	9	17	18	18	—
Concrete*	14	8	14	18	18	—
Concrete*	16	7	12	18	18	—
CMU	6	24	48	48	48	—
CMU	8	16	32	48	48	—
CMU	10	16	24	32	48	—
CMU	12	12	24	32	48	—
CMU	16	8	16	24	40	48

* ACI 318-05 and -08 and -11, Sec. 14.3.4 requires two layers in walls over 10" thick, but "basement walls" are exempted, which presumably applies to retaining walls also. However, the above spacings assume that the specified rebar will be placed on each face.

11.2 Appendix B - Development and Lap Lengths

Appendix B - Development and Lap Lengths

Lap Splice Lengths(1) and Hooked Bar Embedments (inches)

Bar Size		Masonry (2) f^{1}_{m}=1500 psi		Concrete (3)		
		Grade 40	Grade 60	2000 psi	3000 psi	4000 psi
#4	L	20	24	20.9	17.1	14.8
	H(4)			9.4	7.7	6.7
#5	L	25	30	26.2	21.4	18.5
	H(4)			11.8	9.6	8.3
#6	L	30	36	31.4	25.6	22.2
	H(4)			14.1	11.5	10.0
#7	L	35	42	45.8	37.4	32.4
	H(4)			16.5	13.4	11.6
#8	L	40	48	52.3	42.7	37.0
	H(4)			18.8	15.4	13.3

(1) Min. lap for spliced bars, in., assumes f_y = 60 ksi, per ACI 318-11, Equation (12-1).

(2) 40 bar diameters for f_y = 40 ksi and 48 diameters for f_y = 60 ksi IBC ’12-2107.2

(3) Min. lap is development length x 1.3, assuming Class B splice. Cannot be reduced for stress level.

(4) Assumes standard hook and not reduced by ratio A_s (required) / A_s (provided).

Note that IBC ’12, 2107.2, modifies ACI 530-11, Section 2.1.7.7.1.1 which has the effect of deleting the following
development length equation in ACI 530:

$$\ell_d = \frac{0.13\, d_b^2\, f_y\, \gamma}{K \sqrt{f^{1}_{m}}}$$

γ = 1.0 for #3, #4, #5 bars, 1.4 for #6, #7, and 1.5 for #8
K = Masonry cover but not less than 5 d_b

This requirement resulted in much longer lap lengths and has met with considerable objection.

11.3 Appendix C - Weights of Masonry Walls

Appendix C - Weights of Masonry Walls

Wall Thickness		Concrete Masonry Units											
Solid Grouted Wall		Lightweight 103 pcf				Medium Weight 115 pcf				Normal Weight 135 pcf			
		6”	8”	10”	12”	6”	8”	10”	12”	6”	8”	10”	12”
		52	75	93	118	58	78	98	124	63	84	104	133
Vertical Cores Grouted at	16” o.c.	41	60	69	88	47	63	80	94	52	66	86	103
	24” o.c.	37	55	61	79	43	58	72	85	46	61	78	94
	32” o.c.	36	52	57	74	42	55	68	80	47	58	74	89
	40” o.c.	35	50	55	71	41	53	66	77	46	56	72	86
	48” o.c.	34	49	53	69	40	45	64	75	45	55	70	83

11.4 Appendix D - Summary of Concrete & Masonry Design Formulas

Appendix D - Summary of Concrete & Masonry Design Formulas

CONCRETE (SD)

ϕ = .90 for flexure

= .75 for shear

= .55 for plain concr flexure/shear

ρ_{bal} = $.85 \frac{f_c'}{f_y} \beta \left(\frac{87{,}000}{87{,}000 + f_y} \right) [\beta = 0.85]$

ρ_{max} = $.75_{bal}$

ρ_{min} = $200/f_y$

E_s = 29,000,000 psi

E_c = $57{,}000 \sqrt{f_c}$

n = E_s / E_c

a = $\frac{A_s f_y}{.85 f_c b}$

The general solution for A_s (per CRSI) =

$$\frac{1.7\ f_c'\ bd}{2 f_y} - \frac{1}{2}\sqrt{\frac{2.89 (f_c'\ bd)^2}{f_y^2} - \frac{6.8\ f_c'\ b\ M_u}{\phi\ f_y'^2}}$$

For b = 12", f_y' = 60 ksi , this reduces to:

A_s =

$$0.17\ f_c' d - \sqrt{.029 \left(f_c'\ 4\right)^2 - .0063\ f_c'\ M_u}$$

M_n = $A_s f_y \left(d - a/2\right)$

$M_u \le \phi M_n$

ℓ_{hb} = $\frac{0.02\ f_y\ d_b \times 0.7}{\sqrt{f_c}} \left(\frac{A_s\ req'd}{A_s\ provided} \right)$

or $.8d_b$ or 6"

*ℓ_{db} (#6 and smaller)

$$= \frac{0.024\ d_b f_y}{\sqrt{f_c}} \left(\frac{A_s\ req'd}{A_s\ provided} \right)$$

*ℓ_{db} (#7 and larger)

$$= \frac{.03\ d_b f_y}{\sqrt{f_c}} \left(\frac{A_s\ req'd}{A_s\ provided} \right)$$

* From ACI 12.2.3

Lap length Class B splice = 1.3 ℓ_{db}

v_c = $2\sqrt{f_c}bd$

Plain concr tension = $5\phi\sqrt{f_c}$

Plain concr shear = $2\phi\sqrt{f_c}$

MASONRY (WSD)

F_s = 0.5 f_y (24,000 psi max.)

E_s = 29,000,000 psi

E_m = 750 f_m

n = E_s / E_m

F_b = .33 f_m

v_u = $1.0\sqrt{f_m}$ (50 psi max)

ρ = A_s / bd

k = $\sqrt{(np)^2 + 2np} - np$

j = $1 - k/3$

M_s = $F_s A_s jd$

M_m = $F_b bd^2 \left(kj/2 \right) = Kdb^2$

v_a = V / bd

l_d = $.002 d_b F_s$ (but not less than 12")

MASONRY (LRFD)

a = $A_s f_y / 0.80\ f_m b$

M_n = $A_s f_y \left(d - a/2\right)$

ϕ = 0.90

11.5 Appendix E - References Used For The Development Of This Program

Appendix E - References Used For The Development Of This Program

- ACI 318-05, -08, -11 and -14, published by the American Concrete Institute.
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11.6 Appendix F - Rankine and Coulomb Formulas

Appendix F - Rankine and Coulomb Formulas

The three methods of inputting active soil pressure are the Equivalent Fluid Pressure (EFP) method, Rankine method and Coulomb method.

With the Equivalent Fluid Pressure (EFP) method, the soil active pressure is defined by an equivalent fluid pressure in psf per foot of depth (e.g. 35 psf).

With the Rankine or Coulomb method, you can input the angle of internal friction and the program will compute the horizontal (and vertical, if applicable) K_a by the respective formulas.

For a level backfill, both the Rankine and Coulomb formulas give the same result, except that the latter also takes into account frictional resistance of the wall surface, and inclination of the wall surface (i.e. batter).

The Rankine Formula

$$K_a = \cos\beta \frac{\cos\beta - \sqrt{\cos^2 \beta - \cos^2 \phi}}{\cos\beta + \sqrt{\cos^2 \beta - \cos^2 \phi}}$$

$$K_a = (\text{horiz.}) = \cos\beta\, K_a$$

For level backfill can be written as: $K_a = \tan^2\left(45 - \frac{\phi}{2}\right)$ or $= \frac{1 - \sin\phi}{1 + \sin\phi}$

The Coulomb Formula

$$K_a = \frac{\sin^2(\alpha + \phi)}{\sin^2\alpha\ \sin(\alpha - \delta)\left[1 + \sqrt{\frac{\sin(\phi + \delta)\ \sin(\phi - \beta)}{\sin(\alpha - \delta)\ \sin(\alpha + \beta)}}\right]^2}$$

$$K_a\ (\text{horiz.}) = \cos\delta\, K_a$$

For both formulas:

β = Angle of backfill slope
ϕ = Angle of internal friction
α = 90° - wall slope angle from horizontal
δ = Angle of friction between soil and wall (Assumed in program to be $\phi/2$)