CHAPTER 4 – EXAMPLE PROBLEMS

EXAMPLE 1

The following is a demonstration of the application of SNAP for design of a soil nail wall support for a 31.2 foot high cut. This Example can be loaded in SNAP by selecting File → Example 1.

Geometry

The slope in front of the wall will be horizontal and 25 feet long. The wall will be battered at an angle of 10 degrees from vertical, and will be 31.2 feet high. The *Geometry tab* shown below indicates that the backslope angle directly behind the top of the wall is chosen to be horizontal, and that the slope behind the wall will extend for 59.5 horizontal feet and remain flat.

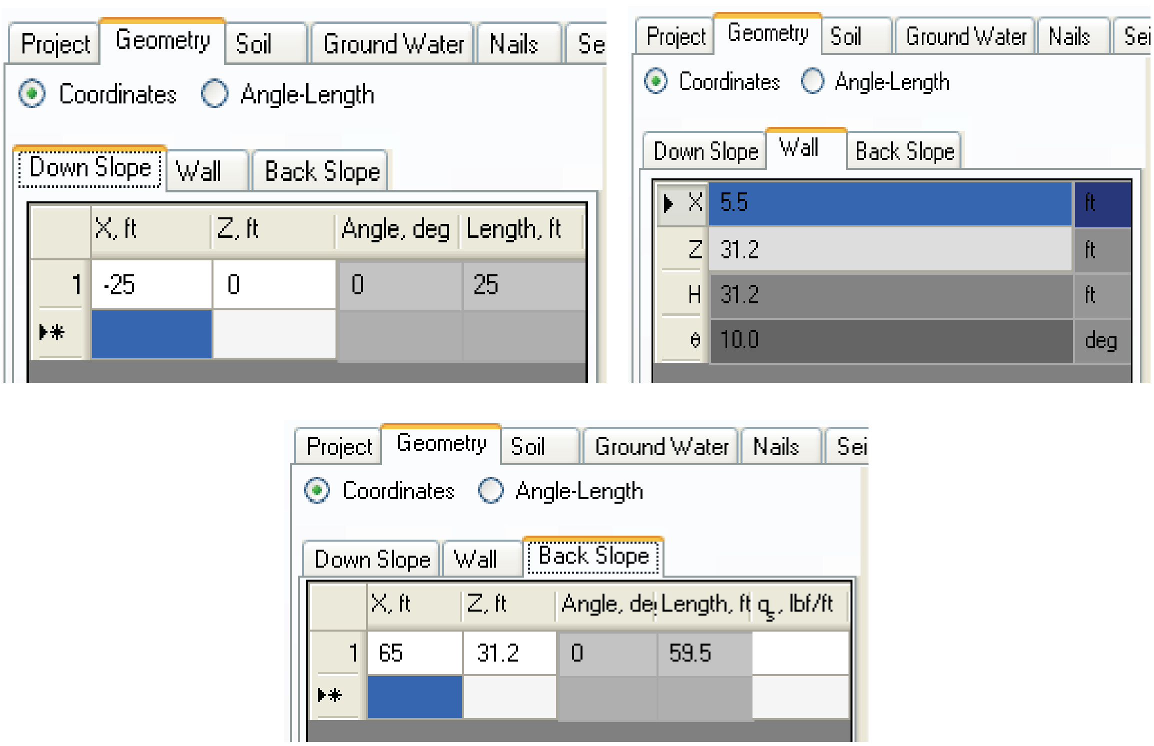


Figure 57. Screen Shot. Example 1, the Geometry tab.

The display area shown on-screen should look like this:

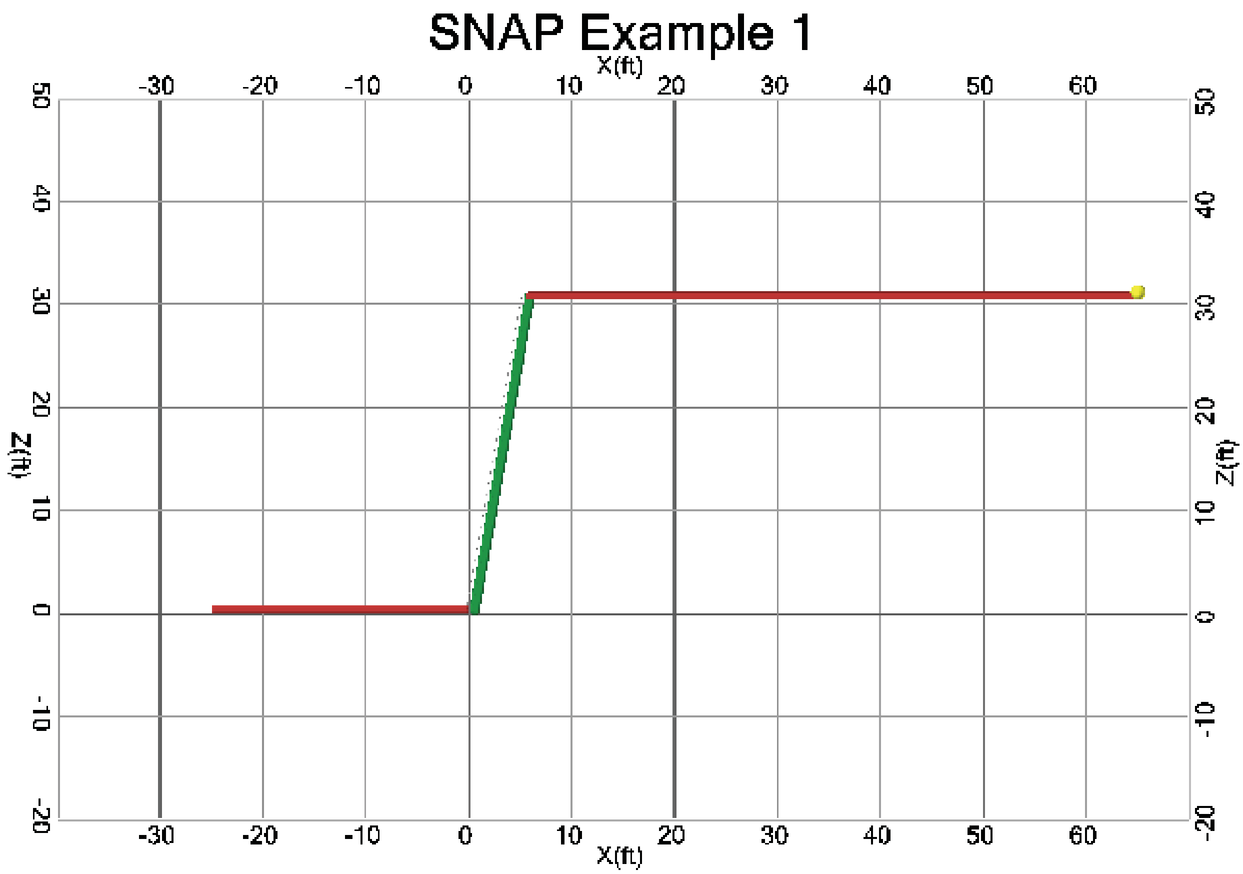


Figure 58. Screen Shot. Example 1, the display area.

(Note: when you start a problem from scratch, the display area won't show any nails until you have entered information on the Nails tab.)

Soil

As shown on the Soil tab below, the soil behind this wall has a moist unit weight of 114.5 lbf/ft^3, a friction angle of 34 degrees, and an ultimate cohesion of 104 lbf/ft^2. The ultimate grout-ground pullout resistance is 15 lbf/in^2, and the bearing capacity factors are N_c = 42.2, N_γ = 41.1, and N_q = 29.4. SNAP uses the drill hole diameter entered on the Nails tab to calculate the ultimate pullout resistance per foot of nail to be 4524 lbf/ft (when you start a problem from scratch, Q_u won't be displayed until the drill hole diameter is entered on the Nails tab).

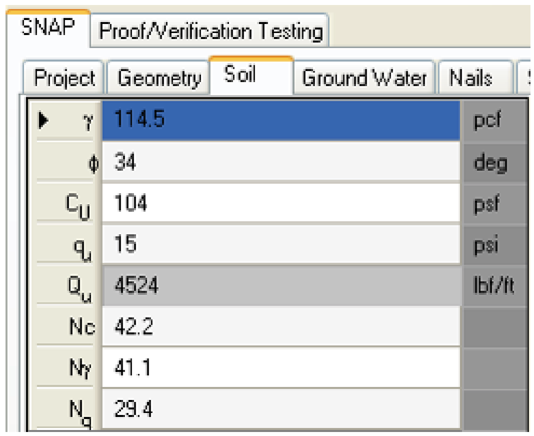


Figure 59. Screen Shot. Example 1, the Soil tab.

Nails

Groundwater is not used in this example, so let's skip to the *Nails tab*. A *trial* nail pattern is input on the Nails tab. Trial nail lengths, vertical spacing, and nail inclination are Uniform, and selected to be 25 feet, 5 feet, and 15 degrees, respectively. The horizontal nail spacing is selected to be 5 feet as well. The drill hole diameter is selected to be 8.0 inches. A bar diameter of 1 in and a cross-sectional area of 0.79 in^2 is chosen, which corresponds to a solid #8 bar (Both area and diameter must be entered to allow for the use of hollow nail bars under certain circumstances). Bar yield strength of 60 kip/in^2 and shear strength of 36 kip/in^2 are chosen. An upper cantilever distance of 3.28 feet (1 meter) is chosen, and the standard recommended resistance factors of 0.50, 0.55, and 0.67 for nail pullout, nail tendon strength, and nail head strength, respectively, are used.

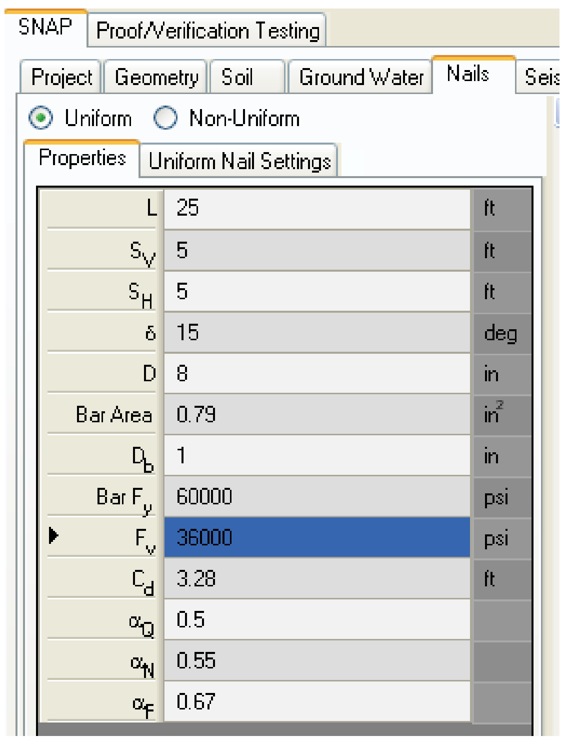


Figure 60. Screen Shot. Example 1, the Nail Properties tab.

The *Uniform Nail Settings sub-tab* displays the nail heights (vertical distance from the bottom of the wall to the nail) and summarizes the nail support diagram for each nail in table form. For example, nail number three has a nail head x-coordinate of 3.16 ft.

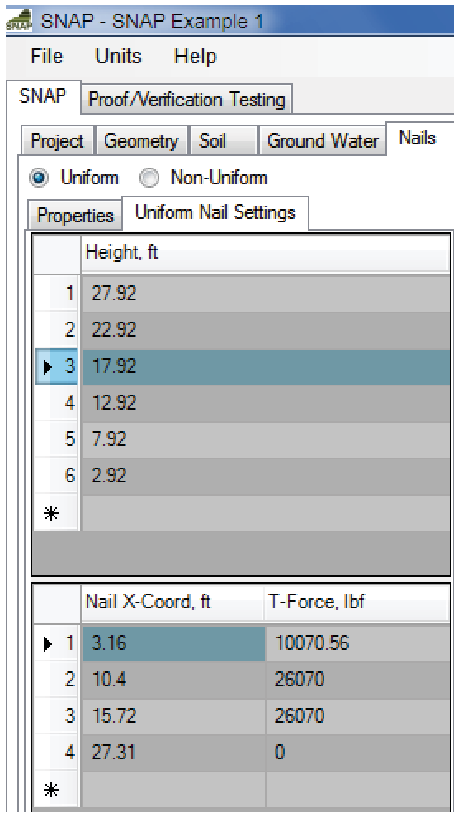


Figure 61. Screen Shot. Example 1, the Uniform Nail Settings tab.

Wall Facing

Seismic coefficients are not used in this example, so let's skip to the *Wall Facing tab*. This example includes inputs for both a temporary shotcrete facing and a permanent cast-in-place concrete facing. Beginning with the Shotcrete facing type, select the *Shotcrete* button at the top of the Wall Facing tab. The *Shotcrete sub-tab* includes 2 options for the nail installation pattern: Offset and Square. An offset pattern is chosen for this Example.

Shotcrete facing inputs are selected for the wall. The welded wire mesh is 6 in. by 6 in., with a wire cross-sectional area of 0.029 in^2, a reinforcement area of 0.058 in^2 per vertical foot of mesh, and an ultimate yield strength of 60 kip/in^2. Horizontal waler bars and vertical bearing bars are chosen to be #4 bars, with an ultimate yield strength of 75 kip/in^2 and two of each type of bar. The program looks up the vertical bearing bar diameter from the bar number, which is 0.5 inch for a #4 bar. 60-inch long vertical bearing bars are chosen. The shotcrete is specified with a compressive strength of 4060 lbf/in^2, and a shotcrete thickness of 3.95 inches is chosen. In reality it is difficult to control the thickness of shotcrete during construction to better than about half an inch but 3.95 inches (rounds to 4) has been chosen purely for the purposes of illustration. The bearing plate is chosen to be 9 inches on each side, and 1 inch thick. The standard recommended pressure factors of 1.0 and 1.0 for flexure and shear, respectively, are used.

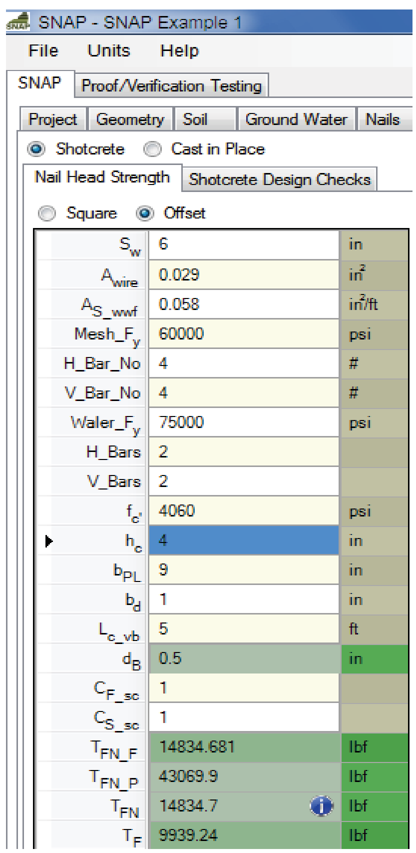


Figure 62. Screen Shot. Example 1, Wall Facing tab, Nail Head Strength for the shotcrete facing.

SNAP calculates the nominal nail head strength and the allowable nail head load for the shotcrete facing on the same tab as all of the inputs. The nominal nail head strength with respect to facing flexure is calculated to be 14834 lbf, and the nominal nail head strength with respect to facing punching shear is calculated to be 43070 lbf. Facing flexure controls, so the maximum nominal nail head load is 14834 lbf. Based on the Nail Head Strength Reduction Factor of 0.67 entered on the Nails tab, the maximum allowable nail head load is 9939 lbf.

On the *Shotcrete Design Checks tab*, the program calculates a predicted nail head service load, using the input nail head service load factor, F_F, entered by the user. This is usually selected to be 0.5. The remainder of this tab includes design and serviceability checks for the shotcrete facing. These indicate that the allowable nail head load is acceptable based on the estimated nail head service load (as outlined in FHWA-SA-96-069R), the one-way unit shear and flexure in the upper cantilever section are acceptable, vertical bearing bars meet minimum length and embedment requirements, and that minimum horizontal waler splice length requirements are met.

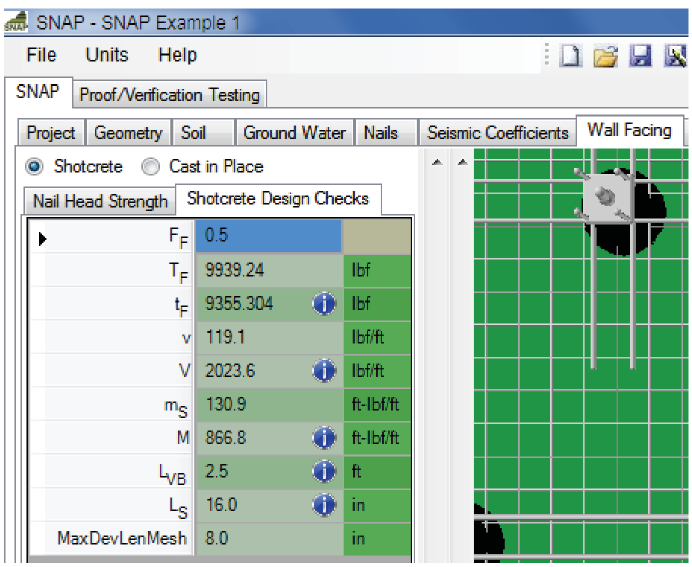


Figure 63. Screen Shot. Example 1, the Shotcrete Design Checks tab.

This example also includes an evaluation of a permanent cast-in-place concrete facing constructed in front of the shotcrete facing for this wall. These inputs are entered by selecting the *Cast-in-Place* button at the top of the *Wall Facing tab*. Now the *Nail Head Strength sub-tab* includes data on the cast-in-place concrete, reinforcement components, and the headed-stud connection system for this facing type. The *CIP Design Checks tab* includes design and serviceability checks relevant to a CIP wall facing, which are similar to those for the shotcrete facing.

On the Nail Head Strength sub-tab, the concrete reinforcement spacing in Example 1 will be 12 inches both horizontally and vertically, and #4 bar with a yield strength of 60,000 psi is chosen for the reinforcements. A CIP facing thickness of 8 inches and a concrete compressive strength of 4060 psi are chosen. The standard recommended pressure factors of 1.0 and 1.0 for flexure and shear, respectively, are chosen. The headed-stud tensile failure factor is chosen to be 0.50, as is recommended.

For the headed-stud connection system, the stud body diameter is chosen to be 0.875 (⅞) inches, and the stud head diameter is chosen to be 1.375 (1 ⅜) inches. The stud head thickness is 0.375 (⅜) inches. The stud length is 5 inches, and the stud spacing is 4.2 inches. Grade 60 steel is chosen for the studs. The plate thickness is 1 inch.

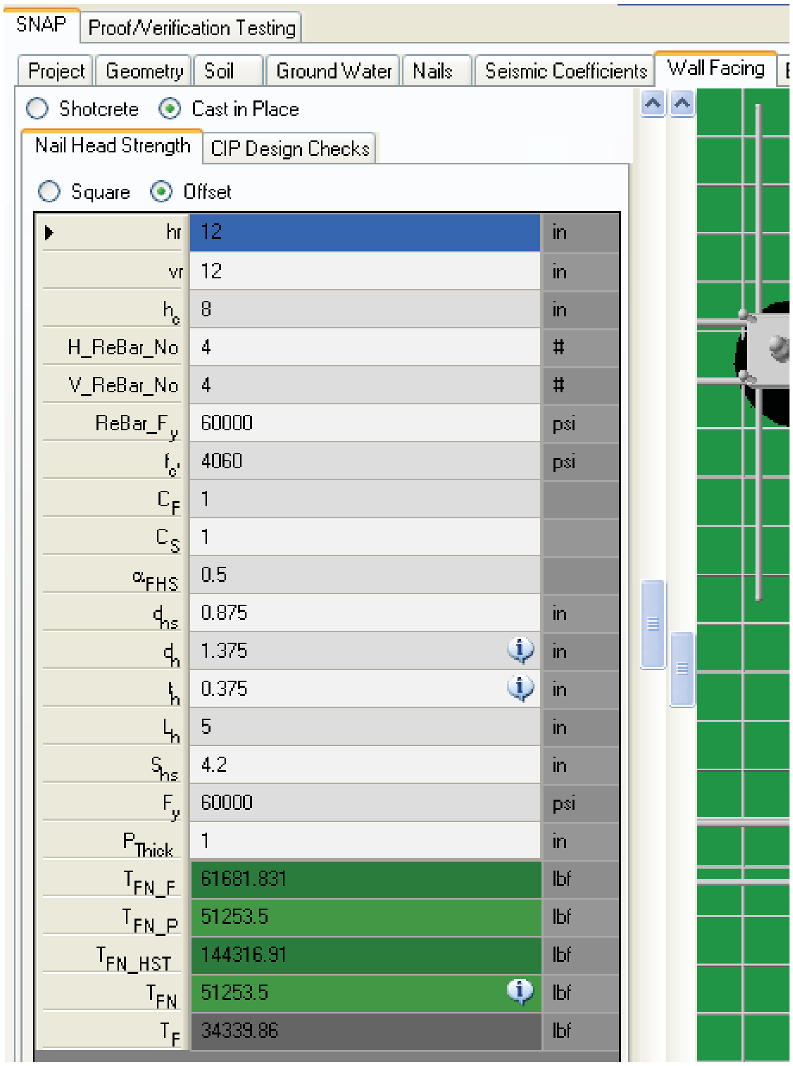


Figure 64. Screen Shot. Example 1, the Cast-in-Place Nail Head Strength tab.

Output information for the cast-in-place concrete facing is displayed in a similar manner to the shotcrete facing. The nominal nail head strength for flexure, punching, and headed-stud tension are calculated and displayed on the Nail Head Strength tab. For Example 1, these are calculated to be 61682 lbf, 51253 lbf, and 144317 lbf, respectively. SNAP selects the lowest of these to use for calculating the allowable nail head load: in this case, the controlling failure mode is punching shear failure at 51253 lbf. Based on the Nail Head Strength Reduction Factor of 0.67 entered on the Nails tab, the maximum allowable nail head load is 34,340 lbf.

Design and serviceability checks, shown on the CIP Design Checks tab, indicate that the allowable nail head load is acceptable based on the estimated nail head service load (as outlined in FHWA-SA-96-069R), the one-way unit shear and flexure in the upper cantilever section are acceptable, that the facing meets minimum reinforcement ratio and minimum reinforcement cover requirements, and that reinforcement distribution in the upper cantilever is satisfactory.

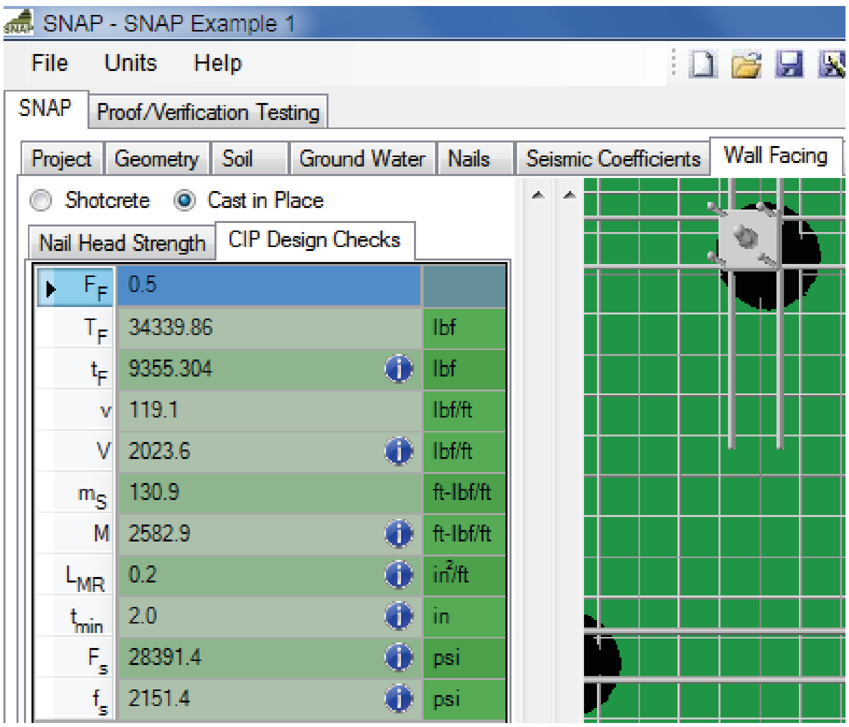


Figure 65. Screen Shot. Example 1, Cast-in-Place facing Design Checks tab.

External Stability

The next tab is the *External Stability tab*. This is only an output tab, and it provides Factors of Safety on sliding, overturning, and bearing capacity, as well as the eccentricity used in the bearing capacity calculation, the effective stress at the base of the wall, and the ultimate and allowable bearing capacity values. Small icons to the right of certain values indicate whether these values meet AASHTO minimum criteria.

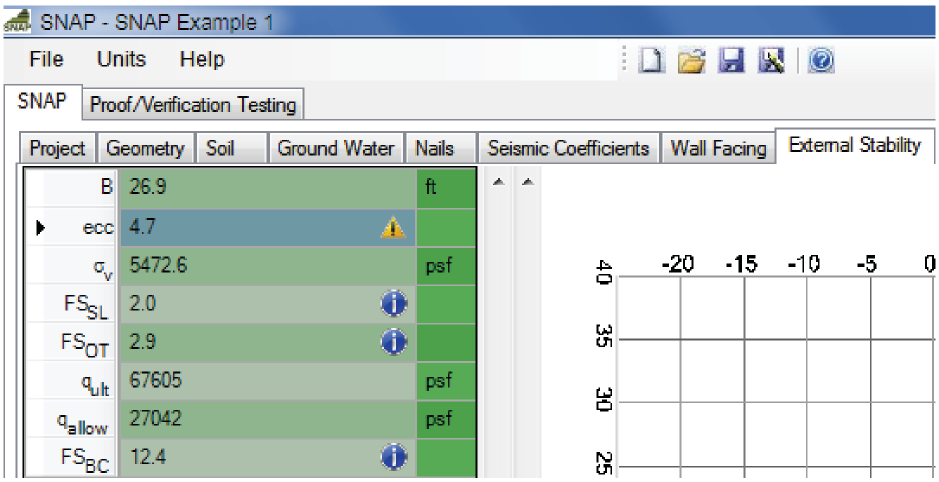


Figure 66. Screen Shot. Example 1, External Stability analysis results.

Global Stability

The *Global Stability tab* (uses the Simplified Bishop Method - circular surfaces only) includes results for global stability, organized into *two sub-tabs*: *Failure Circles and Radius Control*. For this Example, using the *Auto Calc Ranges* feature for selecting the search limits for circular failure surfaces *does not* provide realistic results, showing all 10 lowest FS values on slip circles in the slope above the top nail. By unchecking *Auto Calc Ranges* on the Radius Control tab, and increasing *Upper Fail. Circle Min X* to 9.0, all of the 10 lowest FS circles will pass near the base of the wall.

After making this change, the *Failure Circles tab* indicates that the minimum FS for our example problem is 1.93. The slip circles are shown in the display area, with the selected circle displayed as a much thicker line.

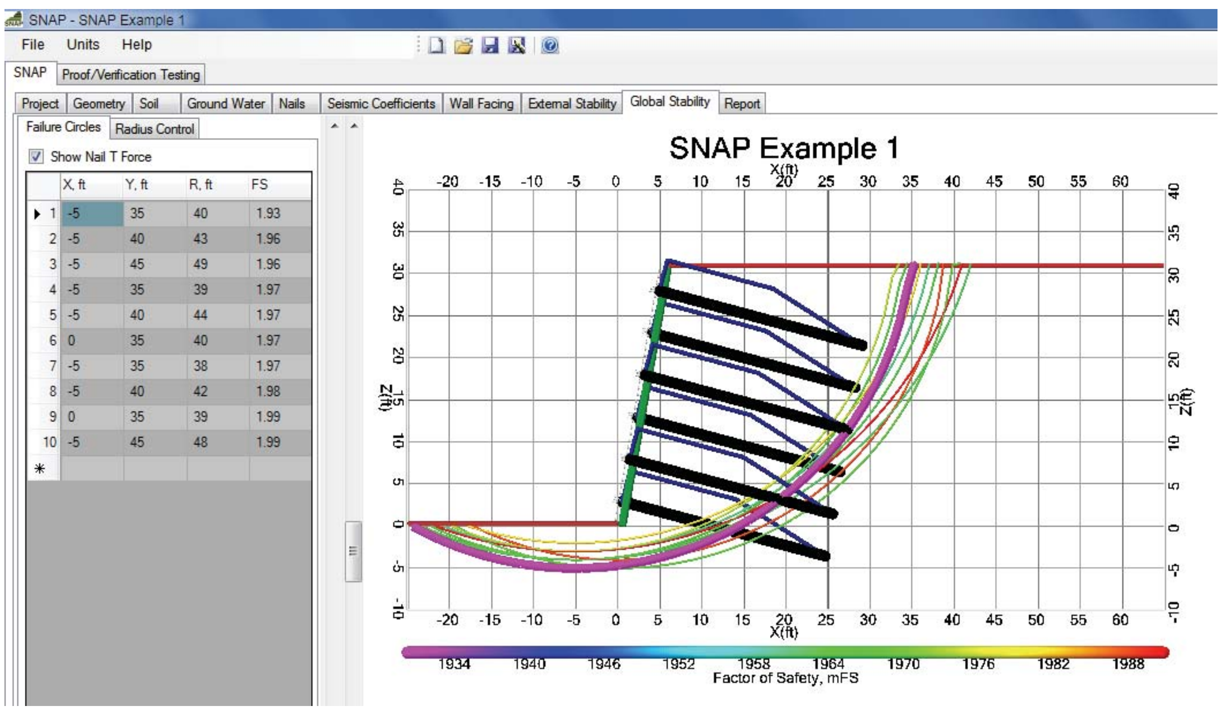


Figure 67. Screen Shot. Example 1, Global Stability tab.

Further adjustment of the values on the *Radius Control tab* will change the minimum FS calculated on the *Failure Circles tab*. Try adjusting these values, and observe how the minimum FS changes.

Report

On the *Report tab*, click *Generate* to create and view the report. It usually takes several seconds to a minute to generate the report; text at the bottom of the screen indicates the progress of report generation. The report will be approximately 13 pages long for this Example problem. The project information from the first tab is displayed on every page, and the report includes all of the input parameters and output results discussed above, as well as graphics from the problem. The last five pages give complete definitions for all the input parameters and output results in the program.

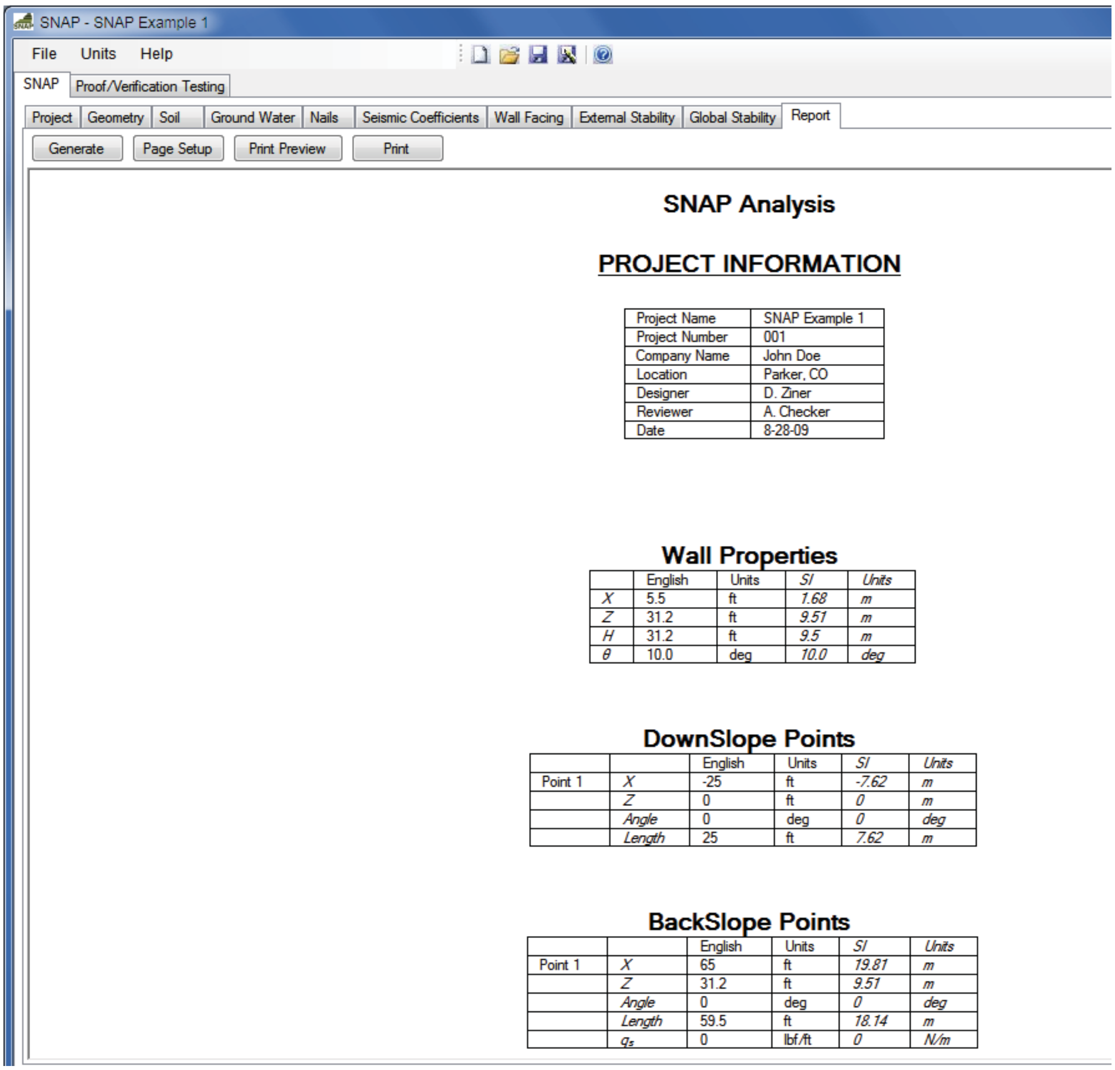


Figure 68. Screen Shot. Example 1, Report generation tab.

EXAMPLE 2

The following is a demonstration of the application of SNAP for design of a different soil nail wall support, for a cut approximately 31 feet high. This example also includes groundwater and seismic loading, but is designed with only a shotcrete facing. It can be loaded into the program by selecting *File* → *Example 2*.

Geometry

The ground surface in front of the wall first slopes down, and then becomes flat, extending a total of 32 feet in front of the wall. The wall will be battered at an angle of 9.5 degrees from vertical, and will be 30.6 feet high. The *Geometry tab* shown below indicates that the backslope angle directly behind the top of the wall is chosen to be 12.88 degrees from horizontal, or a slope of about 4.4:1, extending 14.87 horizontal feet. Above this inclined portion, the slope behind the wall is flat, 24 feet long, and supports a surcharge of 250 psf. After that, the ground slopes upward again at an angle of 9.46 degrees for 36 horizontal feet.

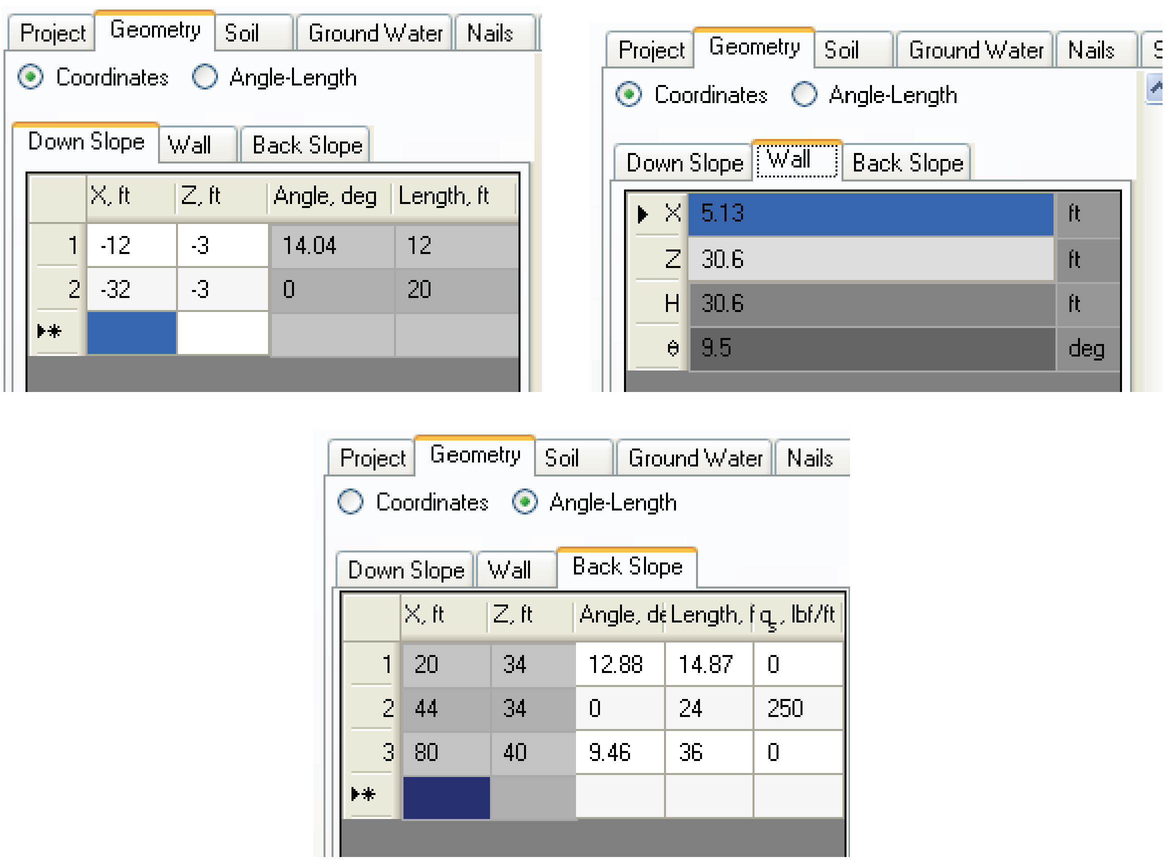


Figure 69. Screen Shot. Example 2, the Geometry tab.

The display area shown on-screen should look like this:

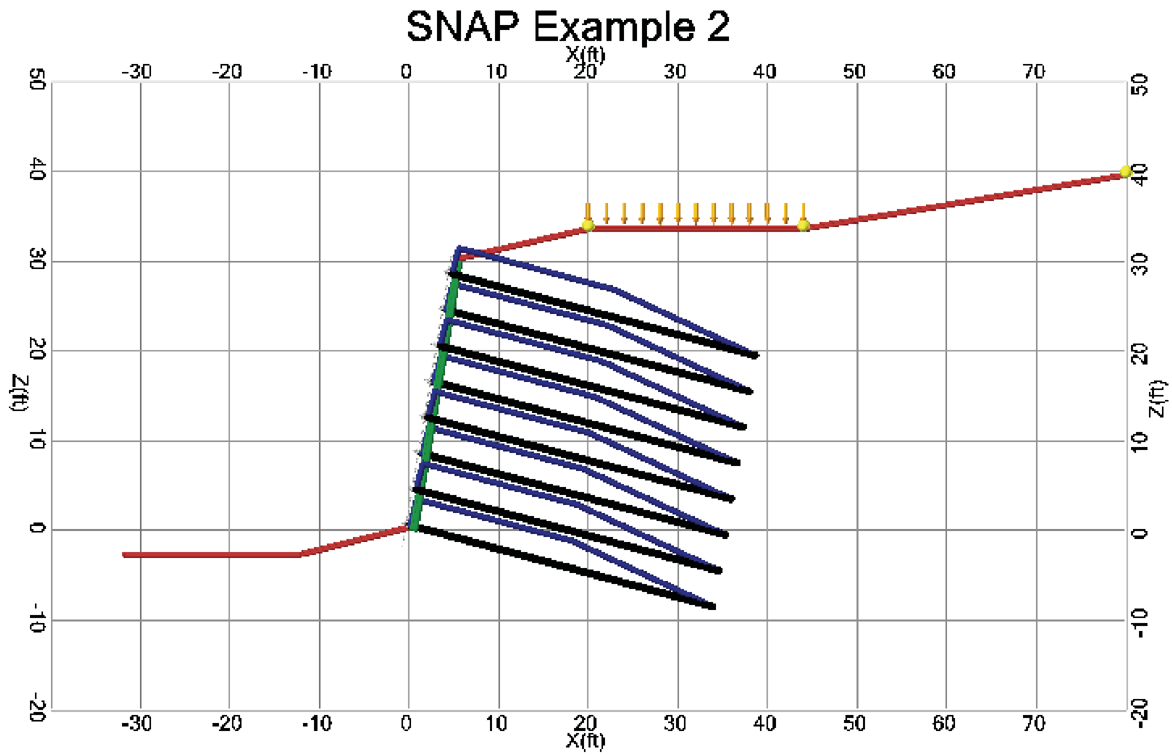


Figure 70. Screen Shot. Example 2, the display area.

Soil

As shown on the *Soil tab* below, the soil behind this wall has a moist unit weight of 125 lbf/ft^3, a friction angle of 36 degrees, and an ultimate cohesion of 150 lbf/ft^2. The ultimate grout-ground pullout resistance is 20 lbf/in^2, and the bearing capacity factors are N_c = 50.6, N_γ = 56.3, and N_q = 37.8. SNAP uses the drill hole diameter entered on the *Nails* tab to calculate the ultimate pullout resistance per foot of nail to be 3958 lbf/ft.

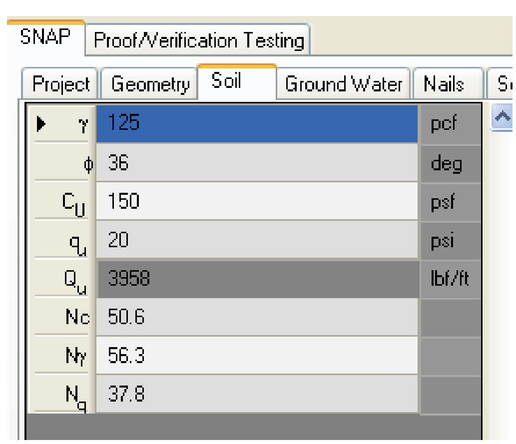


Figure 71. Screen Shot. Example 2, the Soil tab.

Groundwater

This Example problem includes groundwater. The phreatic surface information entered on the *Groundwater tab* indicates that the groundwater surface is shallow at the toe of the wall, and becomes higher within the reinforced/retained soil mass.

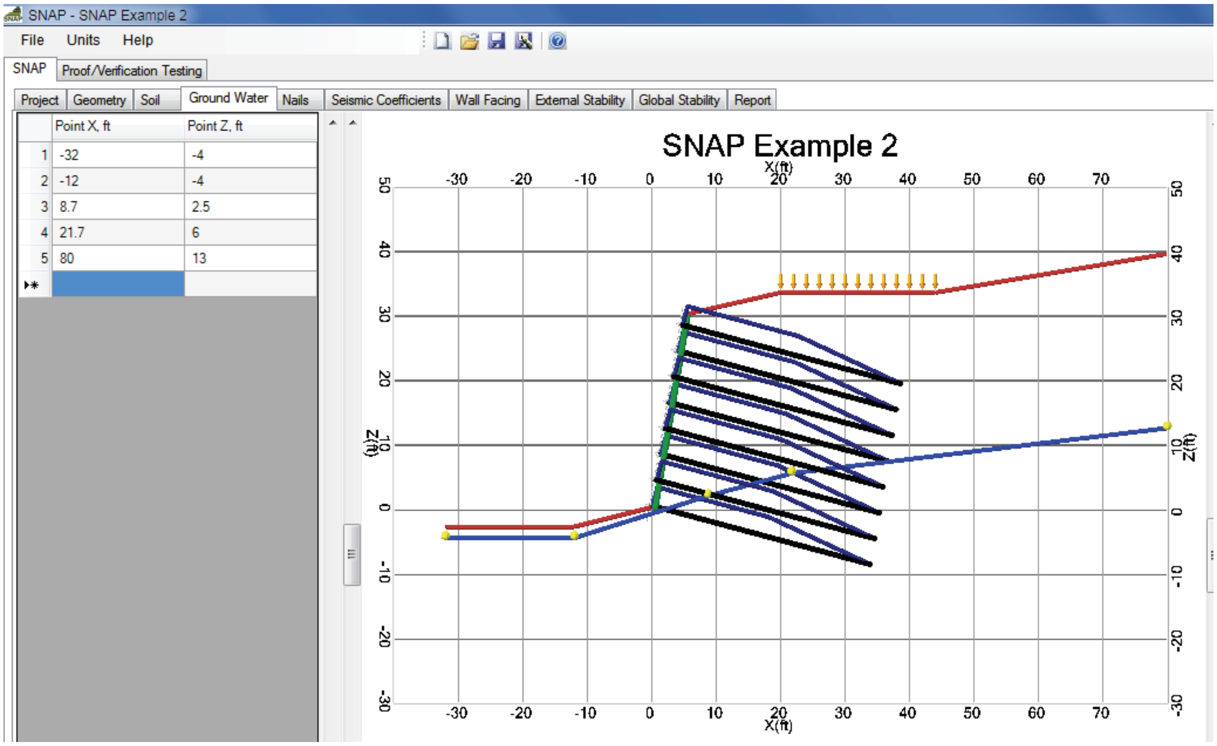


Figure 72. Screen Shot. Example 2, the Groundwater tab.

Nails

A trial nail pattern is input on the *Nails tab*. Trial nail lengths, vertical spacing, and nail inclination are Uniform, and selected to be 35 feet, 4 feet, and 15 degrees, respectively. The horizontal nail spacing is selected to be 7 feet. The drill hole diameter is selected to be 5.25 inches. A 1-inch diameter bar with a cross sectional area of 0.79 in^2 is chosen, which corresponds to a solid #8 bar. Bar yield strength of 75 ksi and shear strength of 36 ksi are chosen. An upper cantilever distance of 2.0 feet is selected. The standard recommended resistance factors of 0.50, 0.55, and 0.67 for nail pullout, nail tendon strength, and nail head strength, respectively, are used.

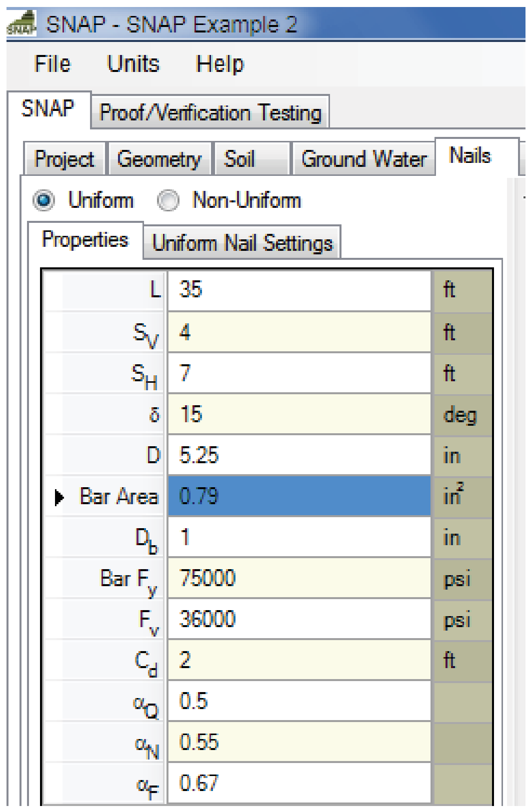


Figure 73. Screen Shot. Example 2, the Nail Properties tab.

The *Uniform Nail Settings sub-tab* displays the nail heights (vertical distance from the bottom of the wall to the nail) and summarizes the nail support diagram for each nail in table form. For Example 2, the allowable nail tendon tensile load (T_N) is smaller than the allowable nail head load (T_F), so the program reports T_N as equal to T_F.

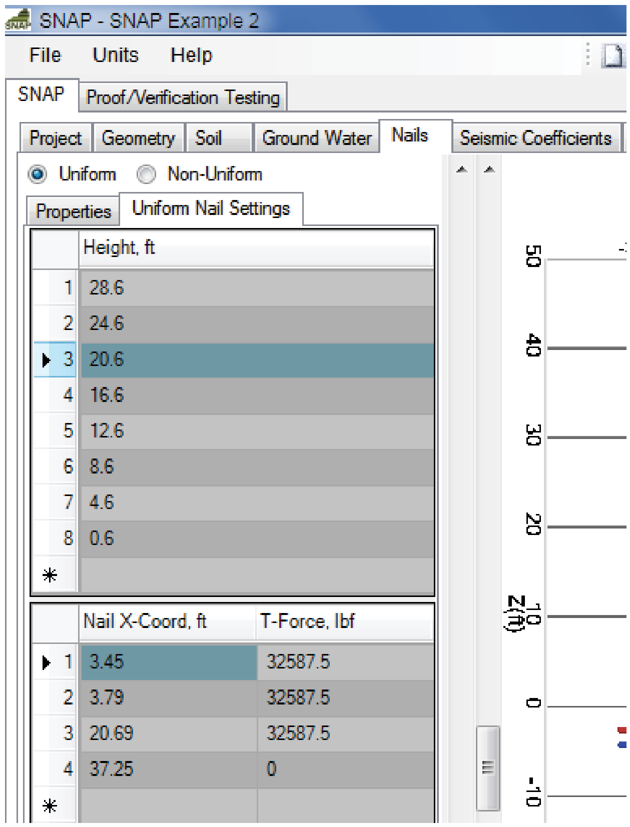


Figure 74. Screen Shot. Example 2, the Uniform Nail Settings tab.

Note that when you create a new file from scratch and go through the data entry, the Nail T-force diagram and corresponding values will not be correct until information about the wall facing is entered.

Seismic Effects

Example 2 demonstrates the use of seismic coefficients in SNAP. A horizontal seismic coefficient (K_h) of 0.18 is entered directly on the *Seismic Coefficients tab*, indicating that a horizontal seismic acceleration equal to 18% of gravity may act on this wall. The Factors of Safety for External Stability and Global Stability will be displayed with the effects of seismic loading as long as the checkbox on the Seismic Coefficients tab is checked. To view the static loading FS, you must return to the Seismic Coefficients tab and uncheck the checkbox.

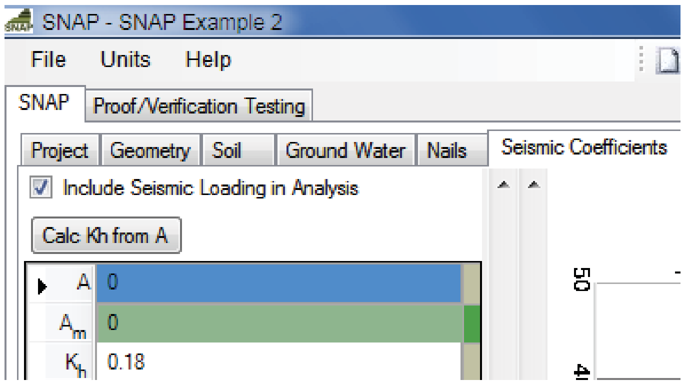


Figure 75. Screen Shot. Example 2, Seismic Coefficients tab.

Wall Facing

This example includes inputs for only a shotcrete facing. The *Shotcrete* button at the top of the *Wall Facing tab* is selected. The *Shotcrete* sub-tab includes 2 options for the nail installation pattern: *Offset* and *Square*. An offset pattern is chosen for this Example.

Example 2 demonstrates how to design a facing using 2 layers of welded wire mesh simultaneously in the shotcrete facing. In this example, one layer of 4x4 inch, W4.0 x W4.0 mesh is selected, along with one layer of 6x6 inch, W2.9 x W2.9 mesh. To enter these in SNAP, the wire spacing is entered as 4 in., with a cross-sectional area of 0.04 in^2, a reinforcement area of 0.178 in^2 per vertical foot of mesh, and an ultimate yield strength of 60000 lb/in^2 i.e. the 2 layers are:

(1) 4x4 W4.0 x W4.0 Area = 0.120 in^2/ft
(2) 6x6 W2.9 x W2.9 Area = 0.058 in^2/ft

The opening size input to SNAP is the smaller of the two (4 inches). The wire cross-sectional area input to SNAP is that of the W4.0 (0.04 in^2). The total cross-sectional area of reinforcement per unit of width is the sum of the areas of the two layers = 0.120 +0.058 = 0.178 in^2/ft.

Horizontal waler bars and vertical bearing bars are chosen to be #4 bars, with an ultimate yield strength of 60 kip/in^2. Two horizontal waler bars and one vertical bearing bar are used. The program looks up the vertical bearing bar diameter from the bar number, which is 0.5 inch for a #4 bar. A 60-inch long vertical bearing bar is chosen. The shotcrete is specified with a compressive strength of 4000 lbf/in^2, and a shotcrete thickness of 8.0 inches is chosen. The bearing plate is chosen to be 8 inches on each side, and 1 inch thick. The standard recommended pressure factors for an 8-inch shotcrete thickness are used: 1.0 for flexure and 1.0 for shear.

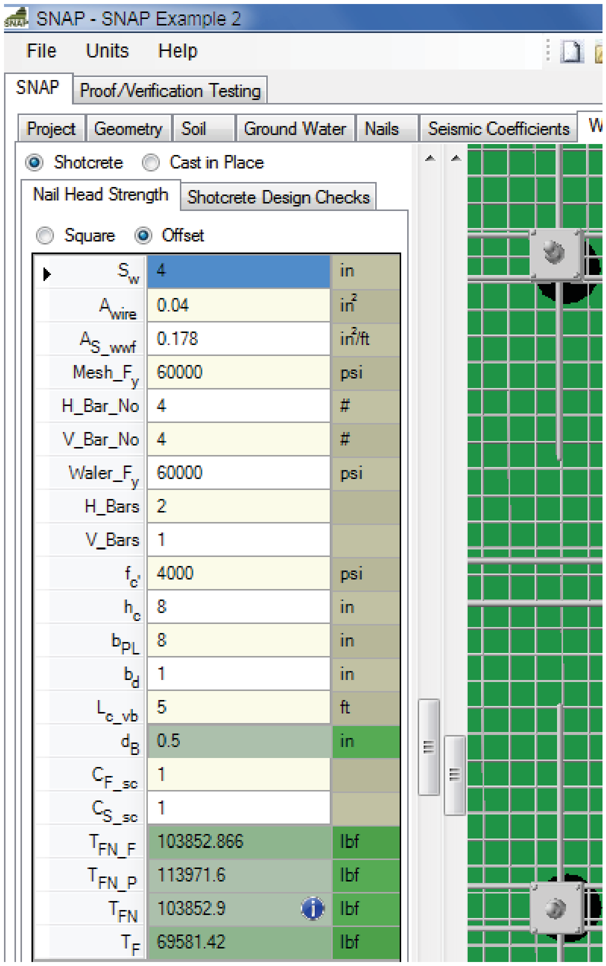


Figure 76. Screen Shot. Example 2, Wall Facing tab, Nail Head Strength for the shotcrete facing.

SNAP calculates the nominal nail head strength and the allowable nail head load for the shotcrete facing on the same tab as all of the inputs. The nominal nail head strength with respect to facing flexure is calculated to be 103853 lbf, and the nominal nail head strength with respect to facing punching shear is calculated to be 113972 lbf. Facing flexure controls, so the maximum nominal nail head strength is 103853 lbf. Based on the Nail Head Strength Reduction Factor of 0.67 entered on the Nails tab, the maximum allowable nail head load is 69581 lbf.

The design and serviceability checks for the shotcrete facing are shown on the *Shotcrete Design Checks tab*. These indicate that the allowable nail head load is acceptable based on the estimated nail head service load (as outlined in FHWA-SA-96-069R), the one-way unit shear and flexure in the upper cantilever section are acceptable, vertical bearing bars meet minimum length and embedment requirements, and that minimum horizontal waler splice length requirements are met.

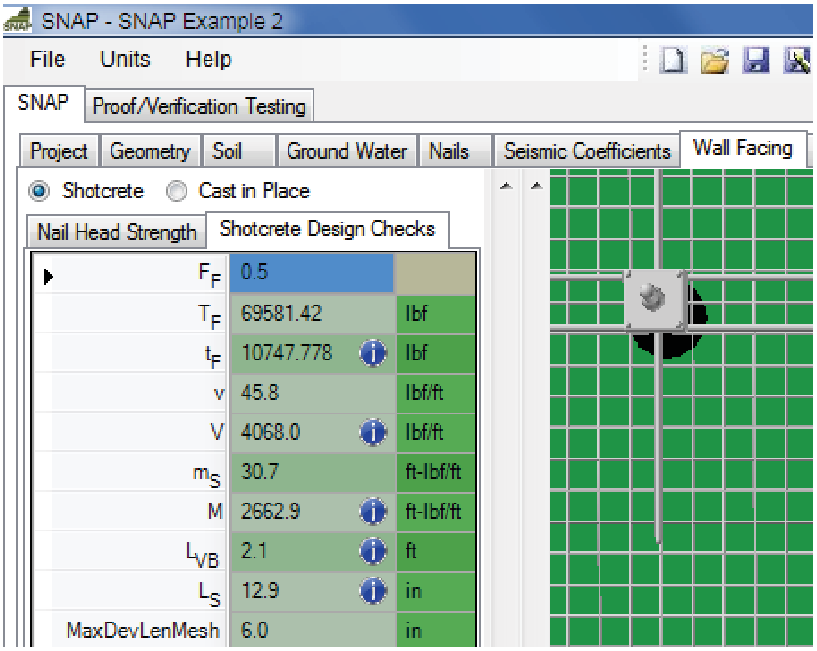
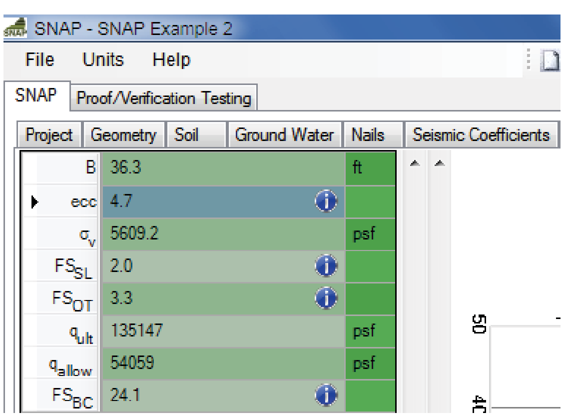


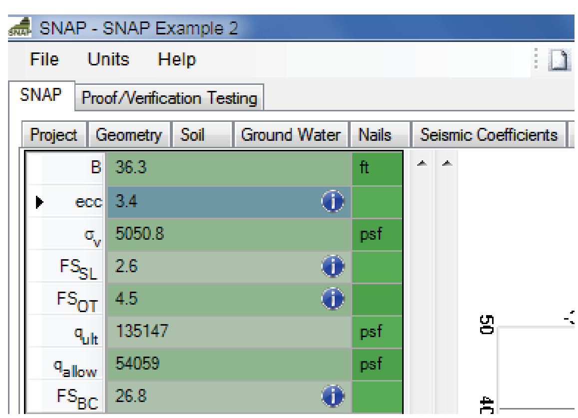
Figure 77. Screen Shot. Example 2, the Shotcrete Design Checks tab.

External Stability

The next tab is the *External Stability tab*. This is only an output tab, and it provides Factors of Safety on sliding, overturning, and bearing capacity, as well as the eccentricity used in the bearing capacity calculation, the effective stress at the base of the wall, and the ultimate and allowable bearing capacity values. To see the results for when seismic loading is included, make sure the *checkbox* on the Seismic Coefficients tab is checked. To see the static FS results, make sure this box remains unchecked. Small icons to the right of certain values indicate whether these values meet AASHTO minimum criteria. These criteria change depending on whether seismic loading is included.



(a)



(b)

Figure 78. Screen Shot. Example 2, External Stability tab showing (a) the results for seismic loading conditions and (b) the results for static loading conditions.

Global Stability

The *Global Stability tab* applies the Simplifed Bishop Method of Slices to obtain results for global stability, organized into two sub-tabs: *Failure Circles* and *Radius Control*. The Failure Circles tab indicates that the minimum FS for our example problem is 0.77 for seismic loading, with the lowest 10 FS all less than or equal to 0.81. The minimum FS for static loading is 0.80, with the lowest 10 FS all less than or equal to 0.83. The slip circles are shown in the display area, with the selected circle shown as a much thicker line. Note that the Auto Calc Ranges option was used for this stability calculation.

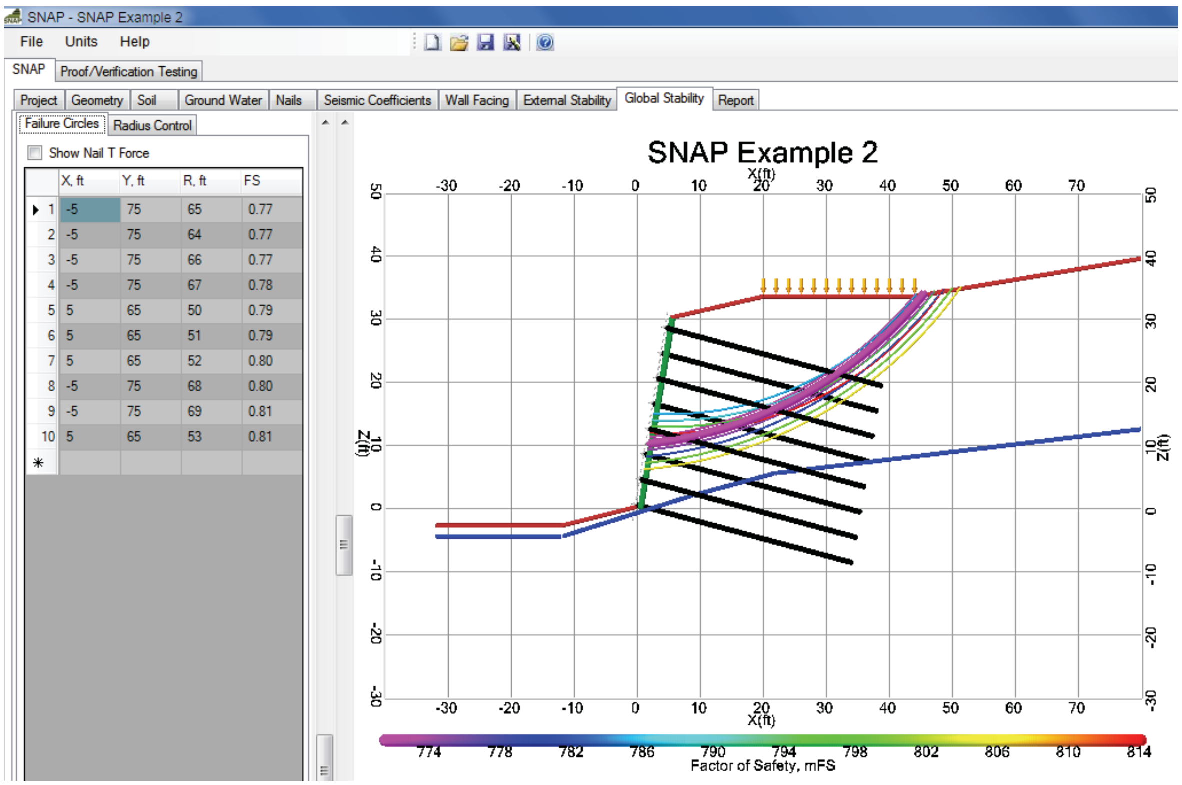


Figure 79. Screen Shot. Example 2, Global Stability tab for seismic (pseudo-static) conditions (k_h= 0.18).

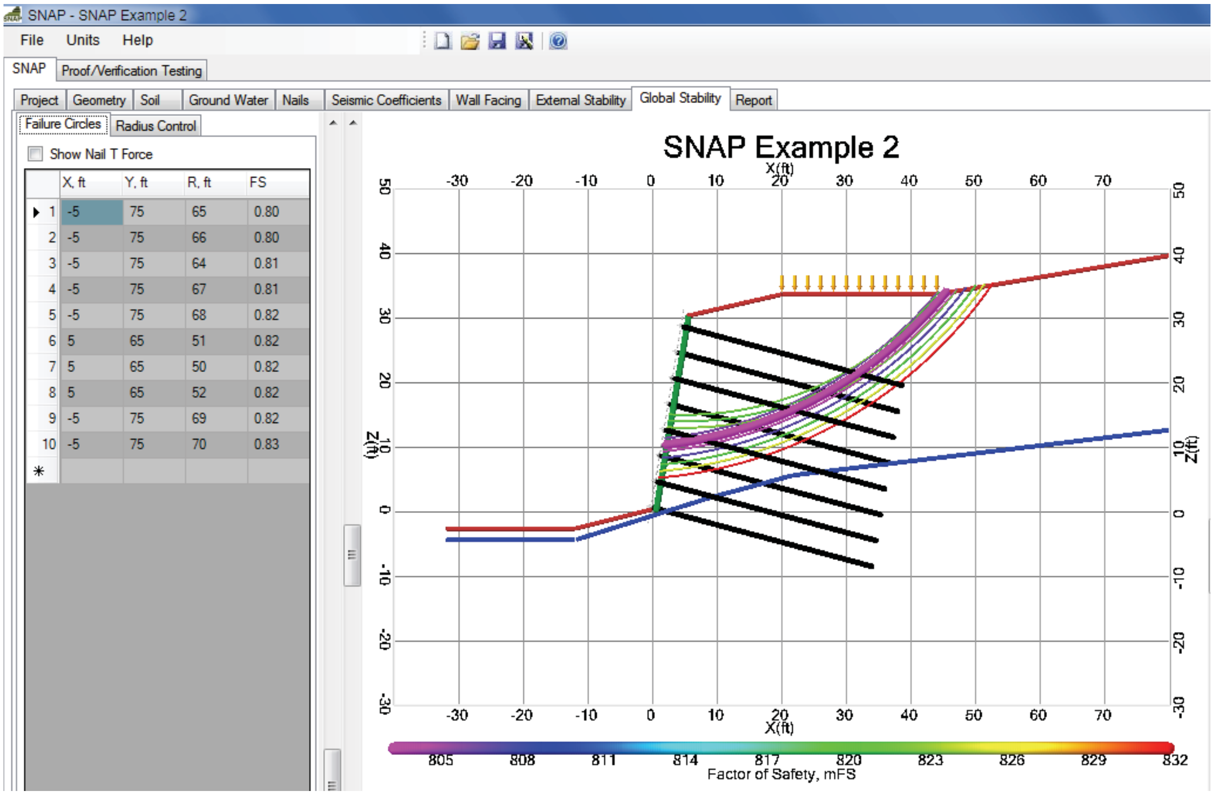


Figure 80. Screen Shot. Example 2, Global Stability tab for static loading conditions.

The *Radius Control tab* allows the user to adjust the range of radius values the program will search within. See Chapter 1 for more information on how SNAP searches for circular failure planes. Adjusting these values will change the minimum FS calculated on the Failure Circles tab. Try adjusting these values, and observe how the minimum FS changes. For this example problem, selecting "Auto Calc Ranges" gives good results.

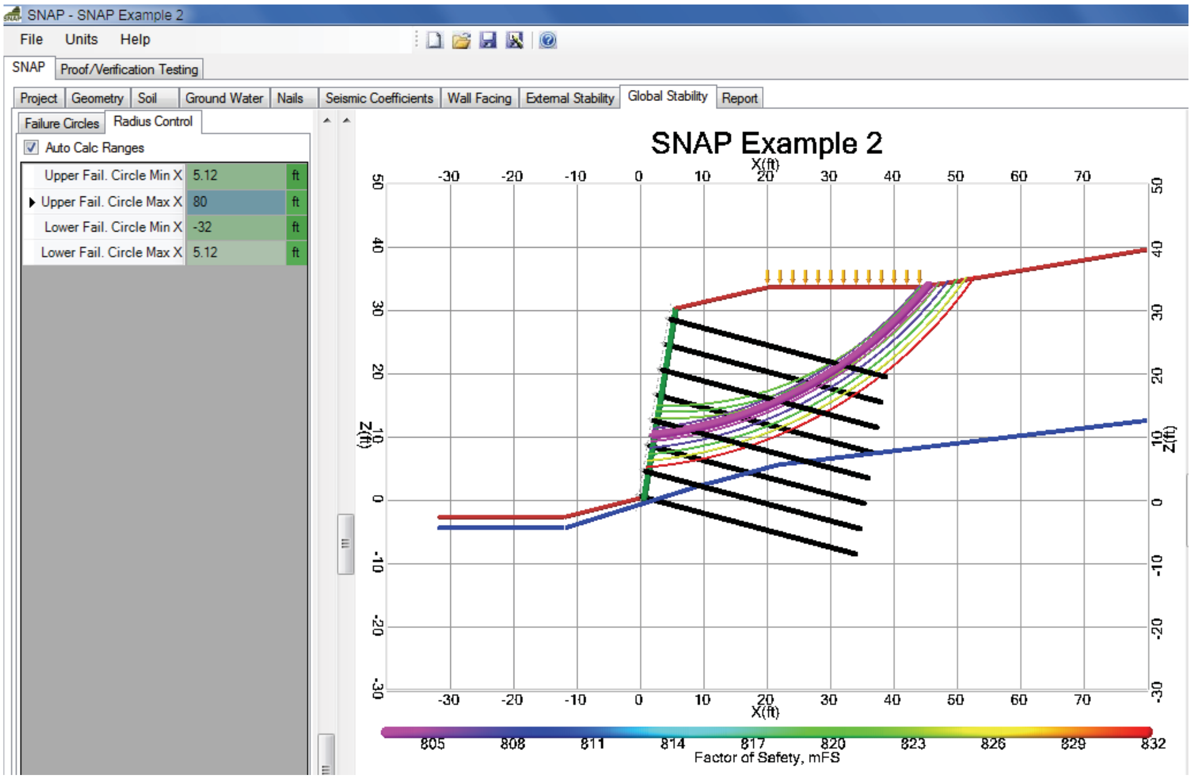
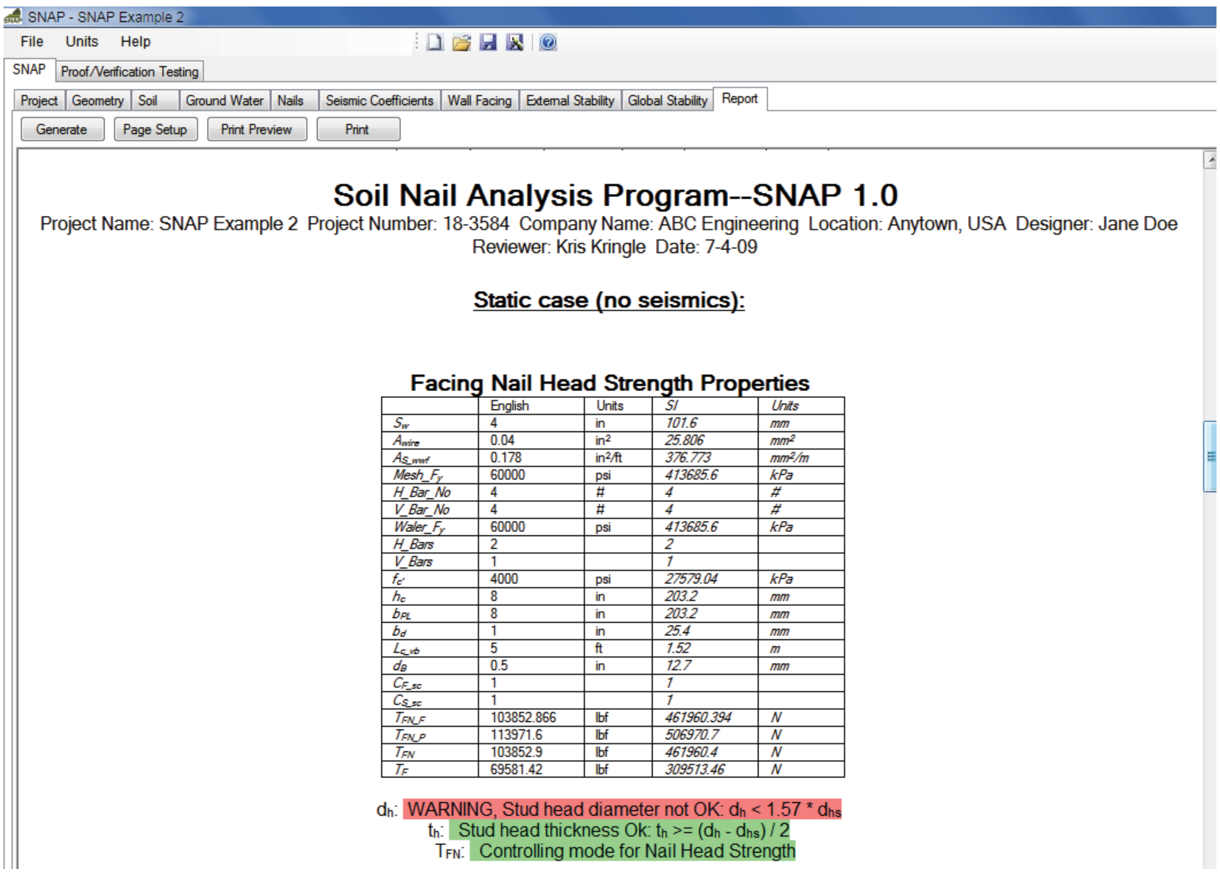


Figure 81. Screen Shot. Example 2, the Radius Control tab.

Report

On the *Report tab,* click *Generate* to create and view the report. It usually takes several seconds to a minute to generate the report; text at the bottom of the screen indicates the progress of report generation. The report will be approximately 21 pages long for this Example problem. The project information from the first tab is displayed on every page, and the report includes all of the input parameters and output results discussed above, as well as graphics from the problem. The last five pages give complete definitions for all the input parameters and output results in the program. When seismic loading is evaluated, such as in this Example, the Report will include output results for both the static and seismic cases.



Soil Nail Analysis Program--SNAP 1.0

Project Name: SNAP Example 2 Project Number: 18-3584 Company Name: ABC Engineering Location: Anytown, USA Designer: Jane Doe Reviewer: Kris Kringle Date: 7-4-09

Static case (no seismics):

Facing Nail Head Strength Properties

	English	Units	*SI*	*Units*
S_w	4	in	*101.6*	*mm*
A_{wire}	0.04	in²	*25.806*	*mm²*
A_{S_wwf}	0.178	in²/ft	*376.773*	*mm²/m*
*Mesh_*F_y	60000	psi	*413685.6*	*kPa*
H_Bar_No	4	#	*4*	*#*
V_Bar_No	4	#	*4*	*#*
*Waler_*F_y	60000	psi	*413685.6*	*kPa*
H_Bars	2		*2*	
V_Bars	1		*1*	
$f_{c'}$	4000	psi	*27579.04*	*kPa*
h_c	8	in	*203.2*	*mm*
b_{PL}	8	in	*203.2*	*mm*
b_d	1	in	*25.4*	*mm*
L_{c_vb}	5	ft	*1.52*	*m*
d_B	0.5	in	*12.7*	*mm*
C_{F_sc}	1		*1*	
C_{S_sc}	1		*1*	
T_{FN_F}	103852.866	lbf	*461960.394*	*N*
T_{FN_P}	113971.6	lbf	*506970.7*	*N*
T_{FN}	103852.9	lbf	*461960.4*	*N*
T_F	69581.42	lbf	*309513.46*	*N*

d_h: WARNING, Stud head diameter not OK: $d_h < 1.57 * d_{hs}$
t_h: Stud head thickness Ok: $t_h >= (d_h - d_{hs}) / 2$
T_{FN}: Controlling mode for Nail Head Strength

Note: D_H is stud diameter and D_{HS} is stud body (reversed from document FHWA-SA-96-069R)

Figure 82. Screen Shot. Example 2, Report tab.