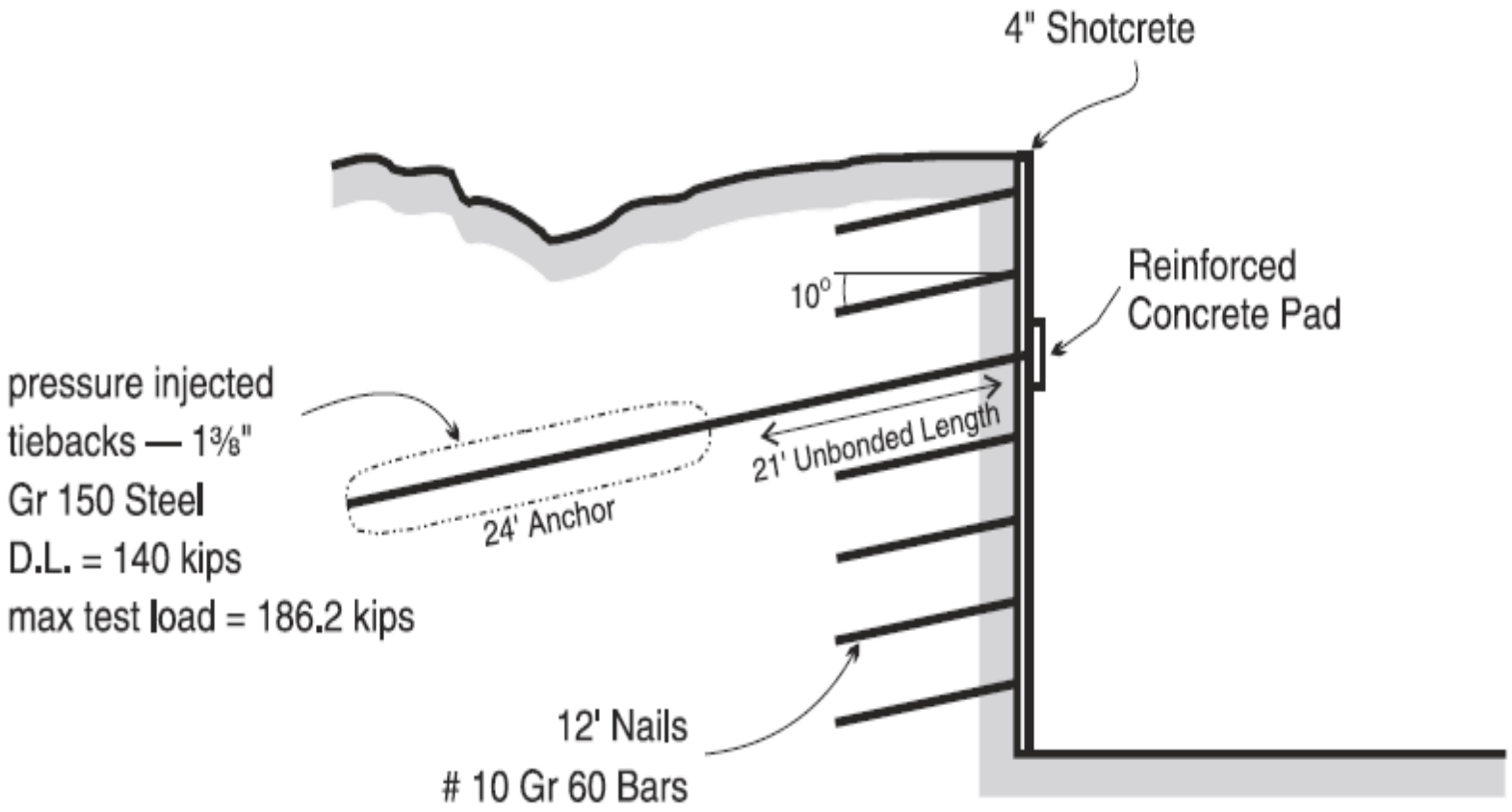
Example Application 6

Full-Scale Test Wall In Sand



Cross section through test wall

Sand Properties – Mohr-Coulomb Model

density	3.63 slugs/ft^3
bulk modulus	1.33x10^6 psf
shear modulus	0.8x10^6 psf
friction angle	36^o
dilation angle	7.5^o
cohesion	0.0

Shotcrete Properties

Young's modulus	4.80×10^8 psf
Poisson's ratio	0.2
moment of inertia	3.00×10^{-3} ft^4
area	0.333 ft^2

Soil Nails and Tiebacks Properties

Property	Row 1 Nails	Row 2 Nails	Row 3 Nails	Grouted Tieback	Ungrouted Portion	Row 4-7 Nails
Young's modulus (psf)	4.2×10^{9}	4.2×10^{9}	4.2×10^{9}	4.2×10^{9}	4.2×10^{9}	4.2×10^{9}
Area (ft^2)	8.5×10^{-3}	8.5×10^{-3}	8.5×10^{-3}	0.0103	0.0103	8.5×10^{-3}
Bond Stiffness ($lb_f/ft/ft$)	6.3×10^{7}	6.3×10^{7}	6.3×10^{7}	6.3×10^{7}	0.0	6.3×10^{7}
Bond Strength (lb_f/ft)	5000	5000	6000	9000	0.0	6000
Yield Strength (lb_f)	73620	73620	73620	222750	222750	73620

Reinforcement Spacing

Row	Spacing (feet)
1	4.5
2	3.5
3	9.0
4	4.5
5	4.5
6	4.5
7	4.5

Modeling Procedure

Step 1 Generate the model grid and assign the material model and boundary conditions to represent the physical system prior to construction of the test wall.

Step 2 Solve for the initial equilibrium state prior to construction.

Step 3 Excavation Stage I – excavate to elevation 98 and install shotcrete lining and Row I soil nails.

Step 4 Excavation Stage II – excavate to elevation 96 and install shotcrete lining and Row 2 soil nails.

Step 5 Excavation Stage III – excavate to elevation 91 and install shotcrete lining and Row 3 soil nails. Install tieback and pretension.

Step 6 Excavation Stage IV – excavate to elevation 87 and install shotcrete lining and Row 4 soil nails.

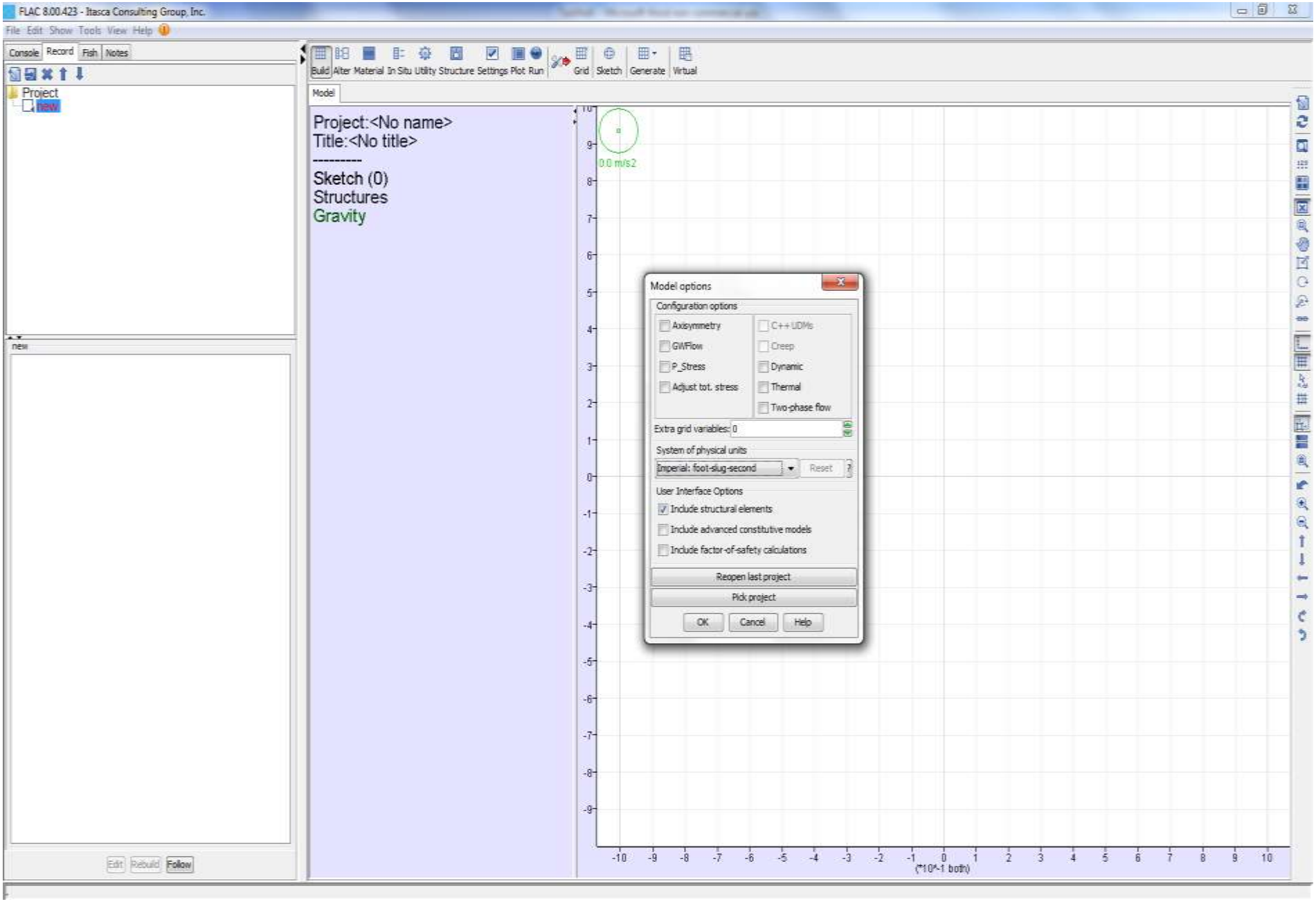
Step 7 Excavation Stage V – excavate to elevation 82 and install shotcrete lining and Row 5 soil nails.

Step 8 Excavation Stage VI – excavate to elevation 78 and install shotcrete lining and Row 6 soil nails.

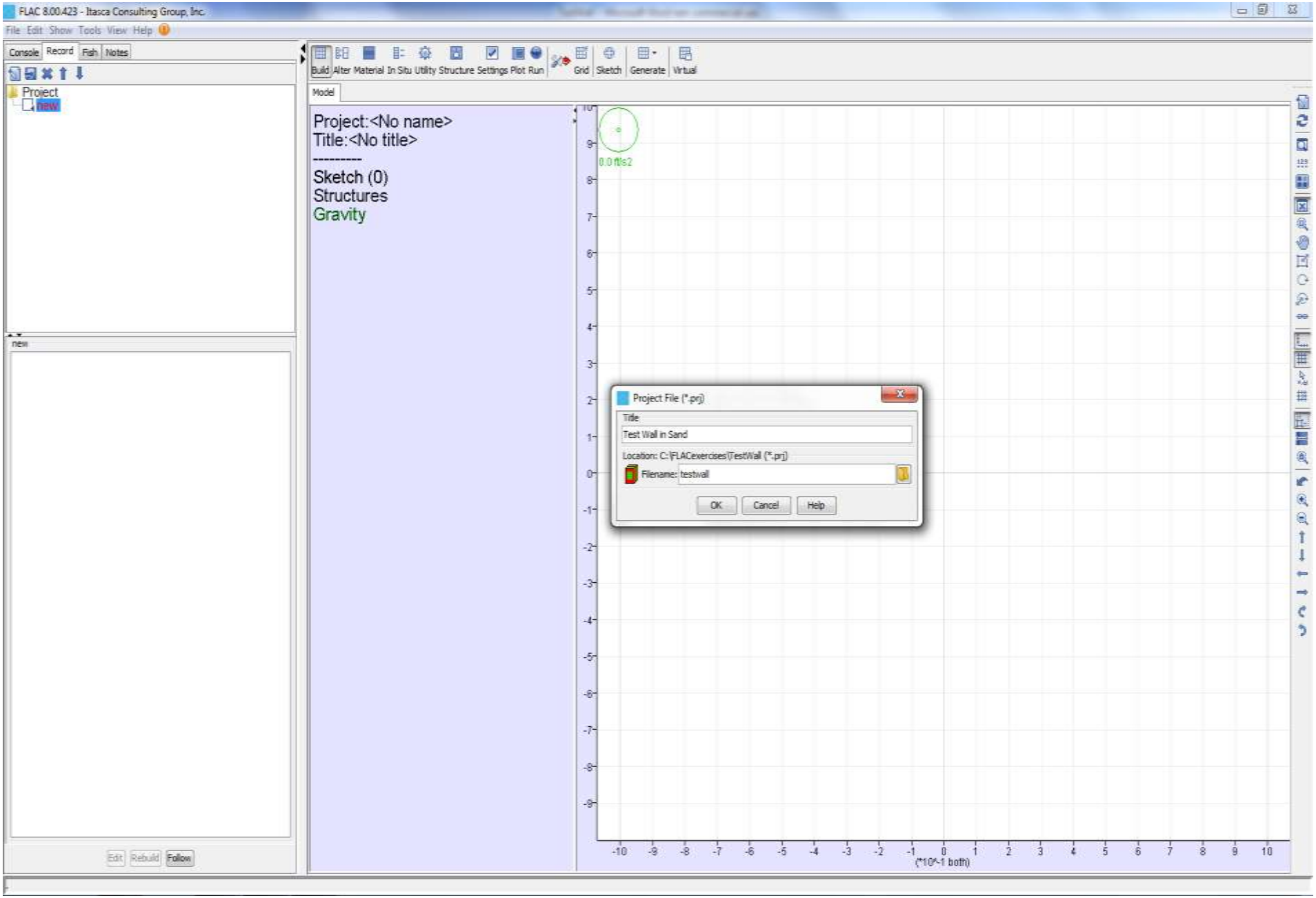
Step 9 Excavation Stage VII – excavate to elevation 73 and install shotcrete lining and Row 7 soil nails.

Step 10 Excavation Stage VIII – excavate to elevation 72 and install shotcrete lining.

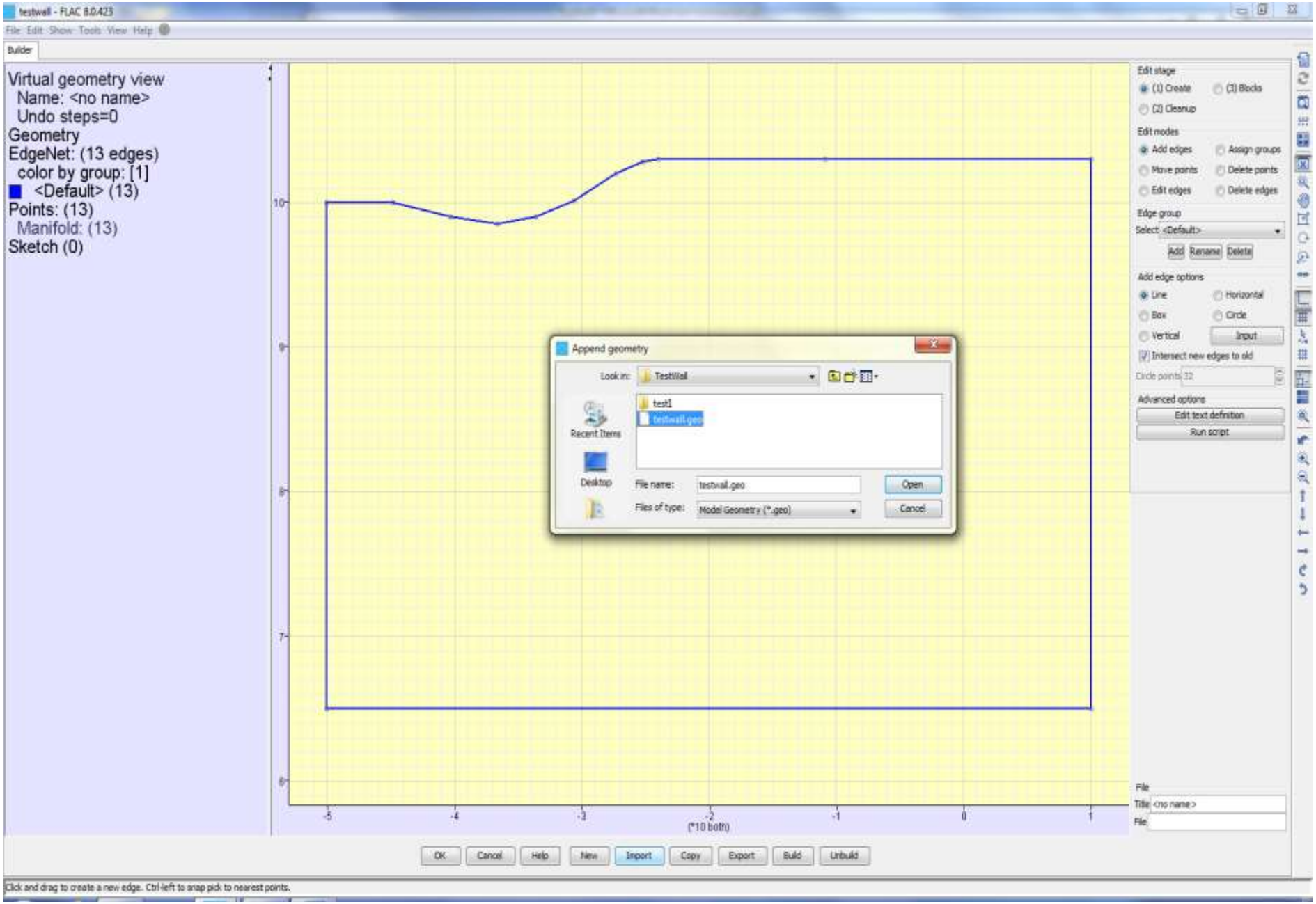
Step 11 Show axial forces along tieback and soil nails. Plot displacements in soil.



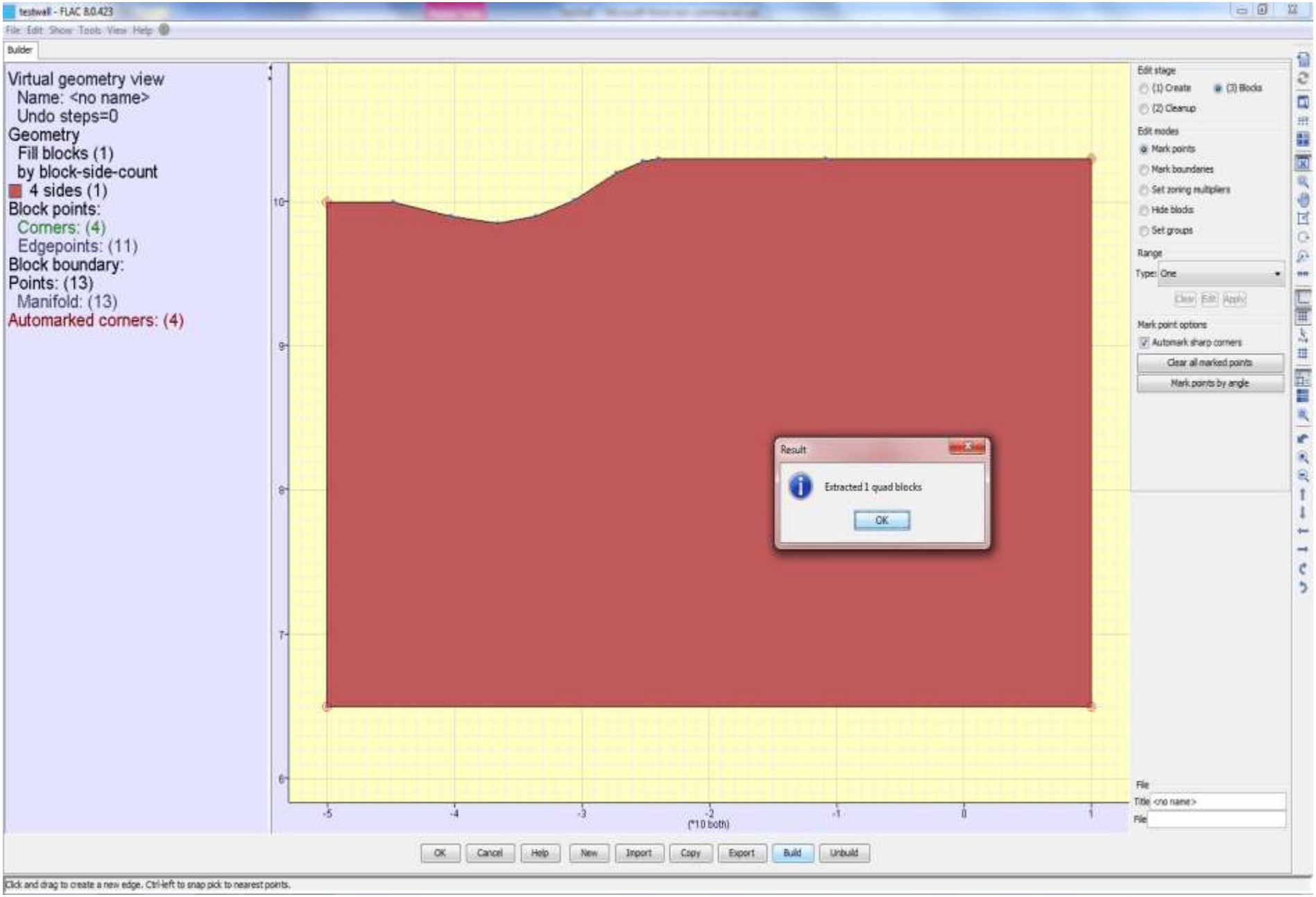
The [Include structural elements] User Interface option will be used for this exercise. The system of units are [Imperial: foot-slug-second].



A project title is assigned, and a project file **testwall.prj** is created and stored in a working directory.

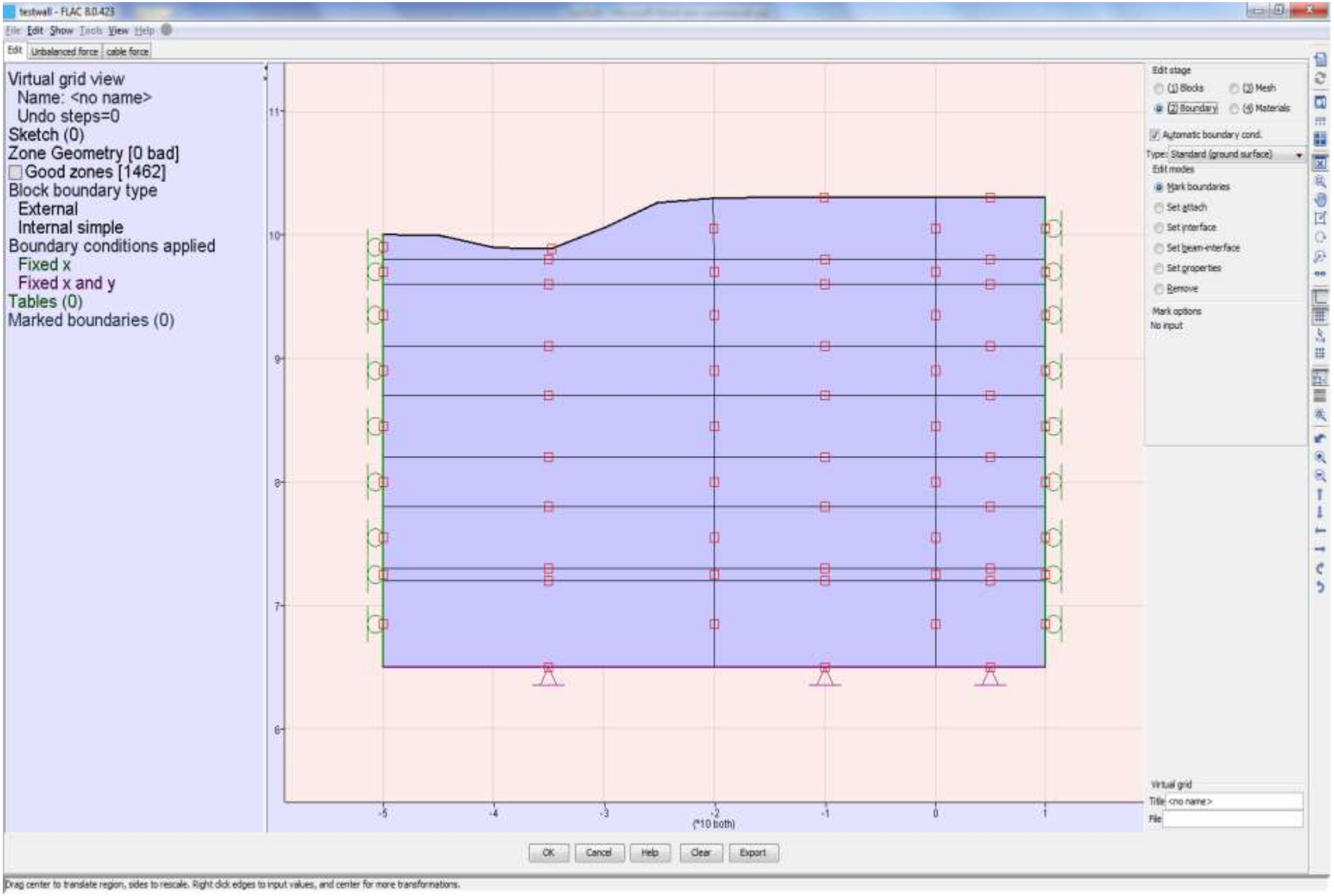


Step 1-1 In the [Geometry Builder] import the boundary geometry file **testwall.geo.** (This geometry can be obtained from a dxf or drawn in the [Sketch] tool.)

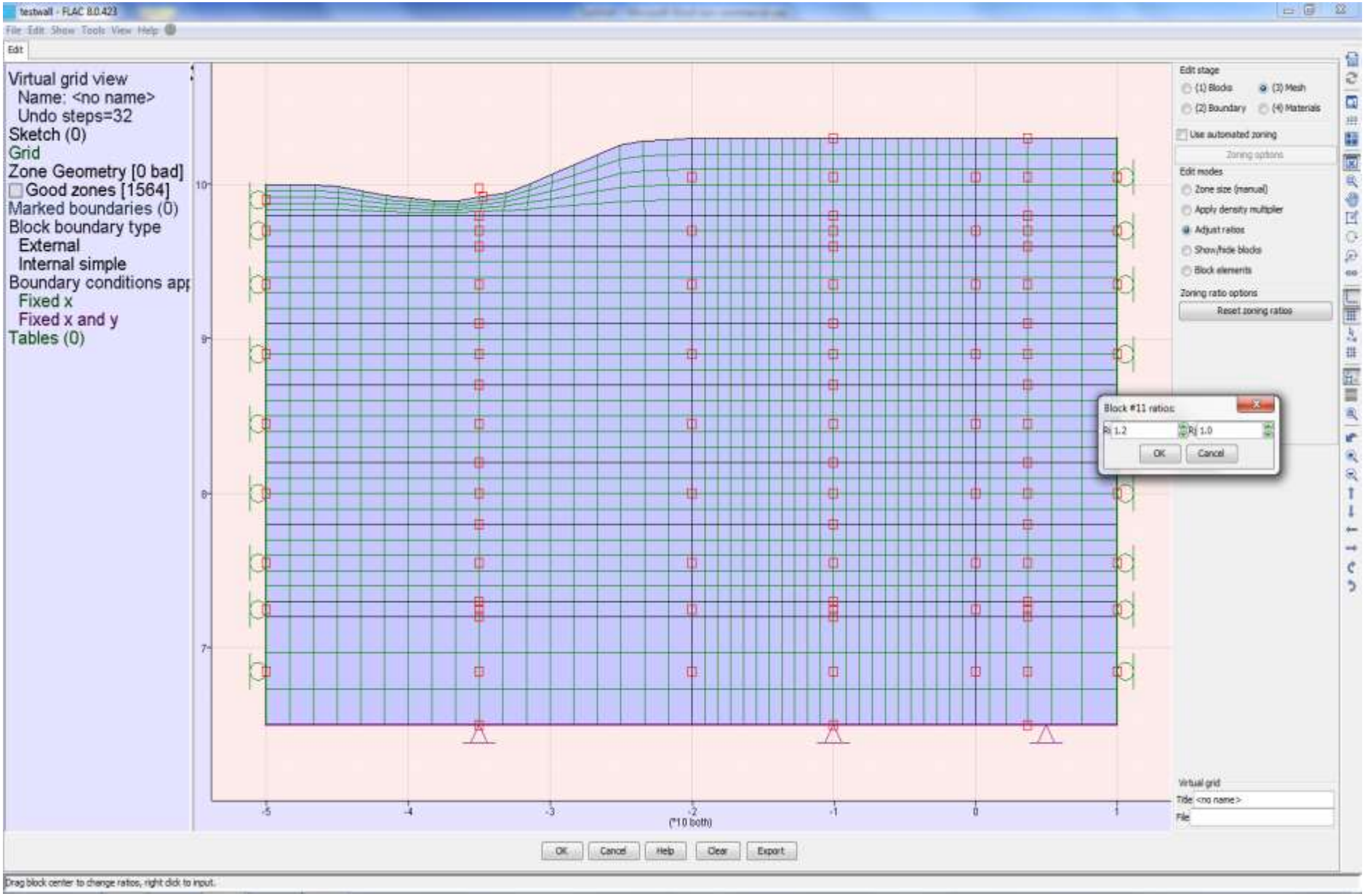


Step 1-2 Check the [Blocks] edit stage and press [Build] to extract one quad block. Press [OK] and exit the [Geometry Builder].

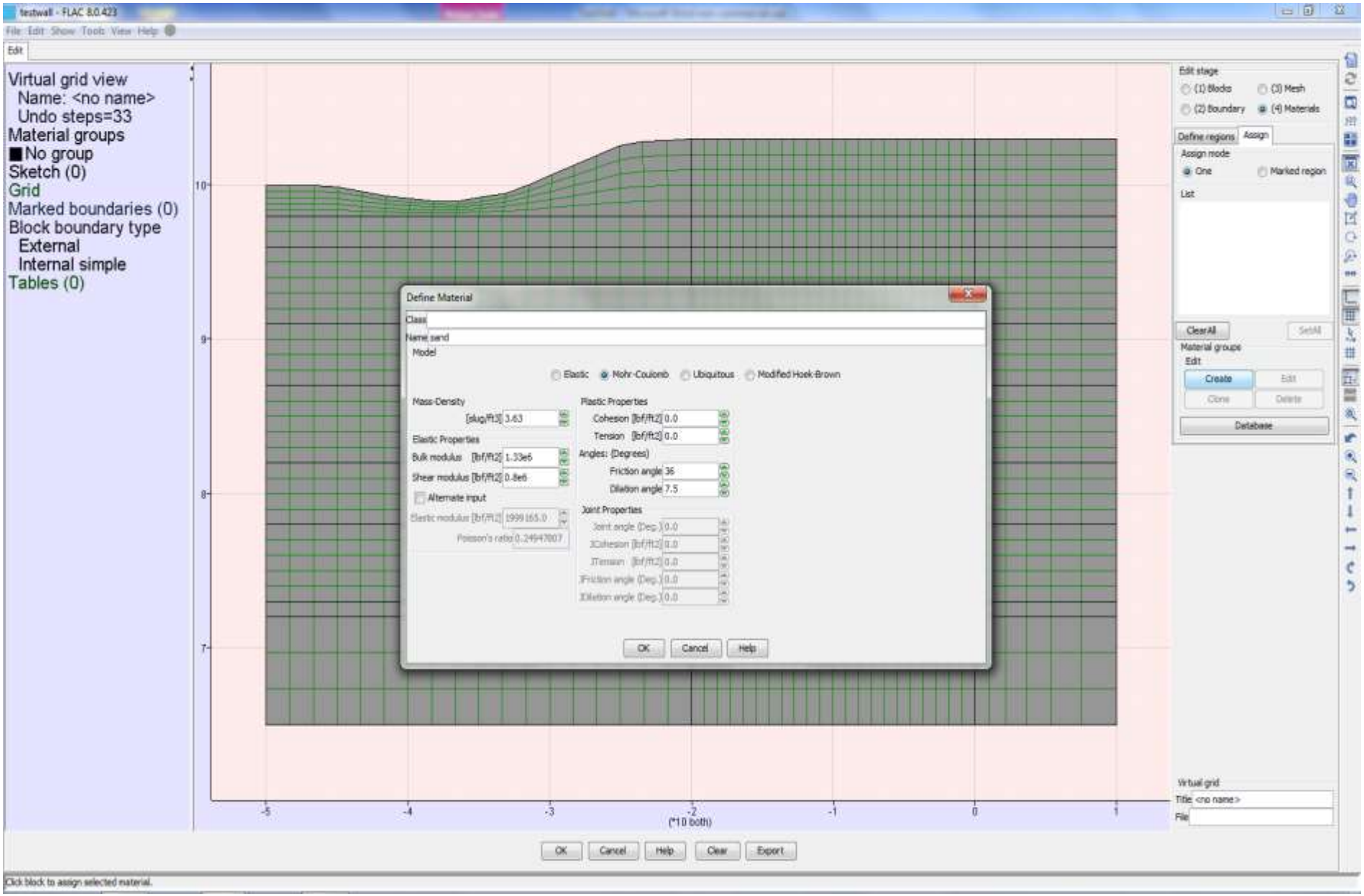
Step 1-3 In the [Blocks] edit stage of the [Edit] tool, add horizontal lines at elevation y = 72, 73, 78, 82, 87, 91, 96 and 98, which correspond to excavation stages. Also, add vertical lines at x = -20 and 0.0. This creates separate blocks in the model to control zoning.



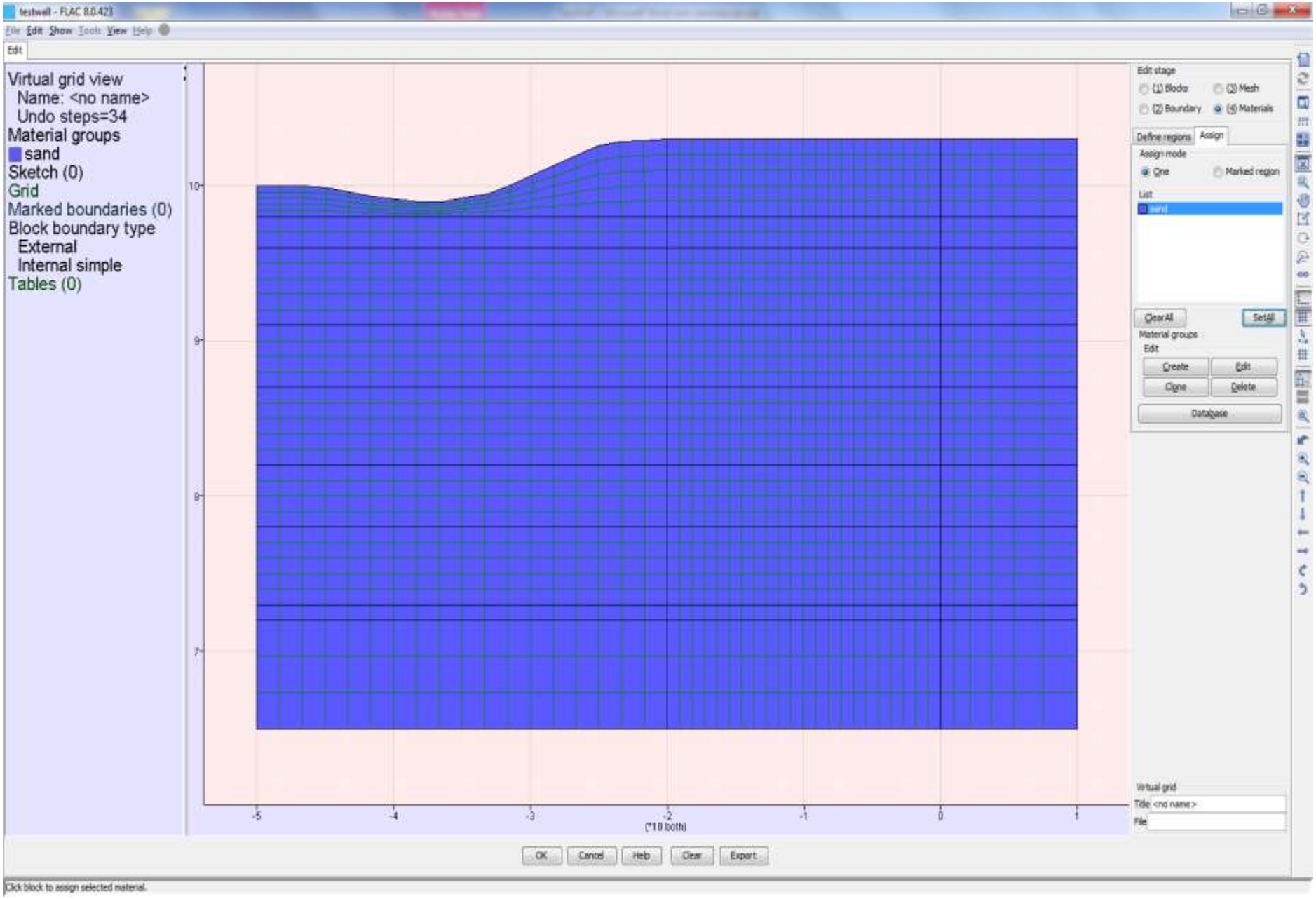
Step 1-4 In the [Boundary] edit stage, set boundary conditions by checking [Automatic boundary cond.].



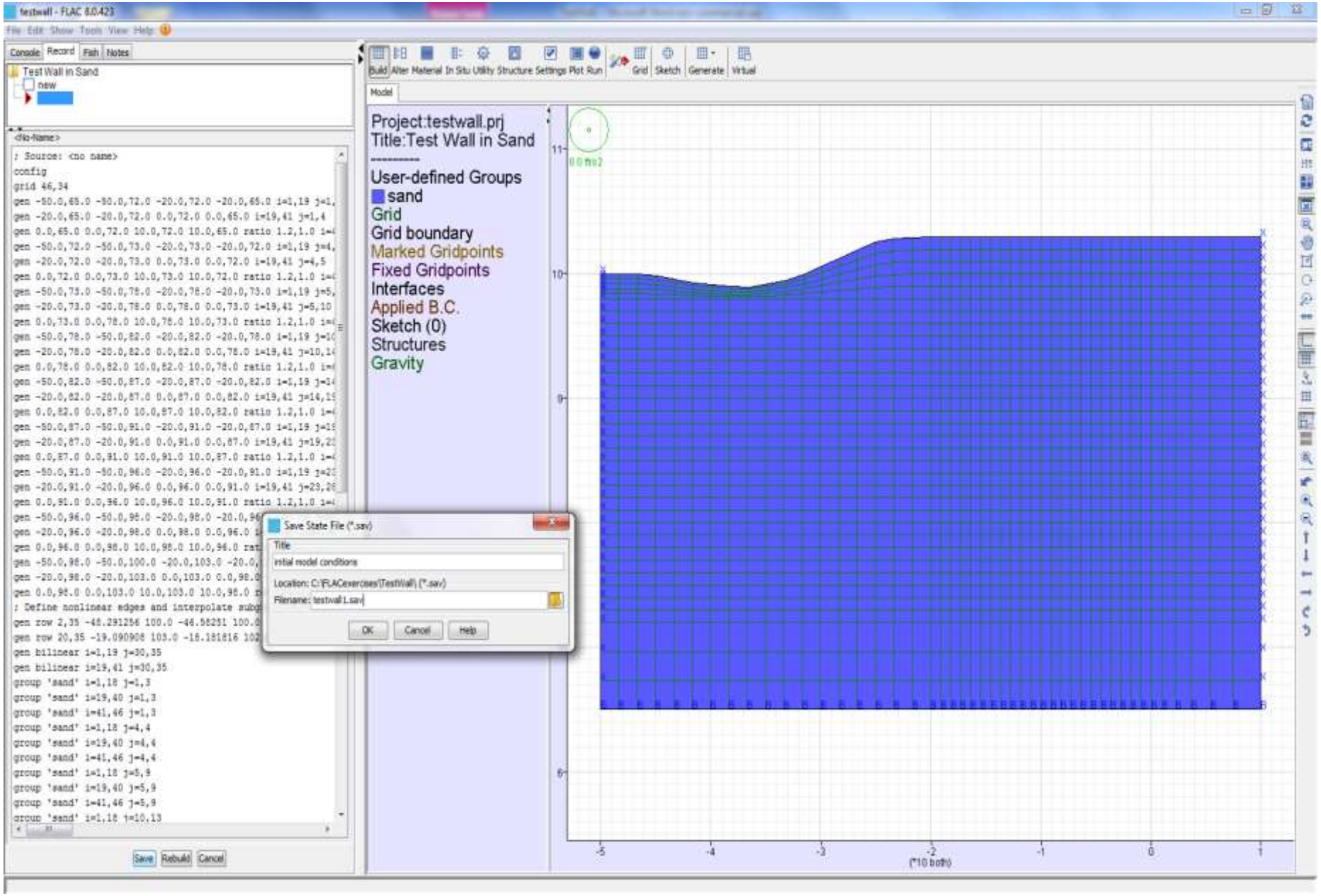
Step 1-5 In the [Mesh] edit stage, uncheck [Use automated zoning] mode and specify zoning manually as shown. Select [Adjust ratios] to adjust zone ratio for the region of zones to be excavated.



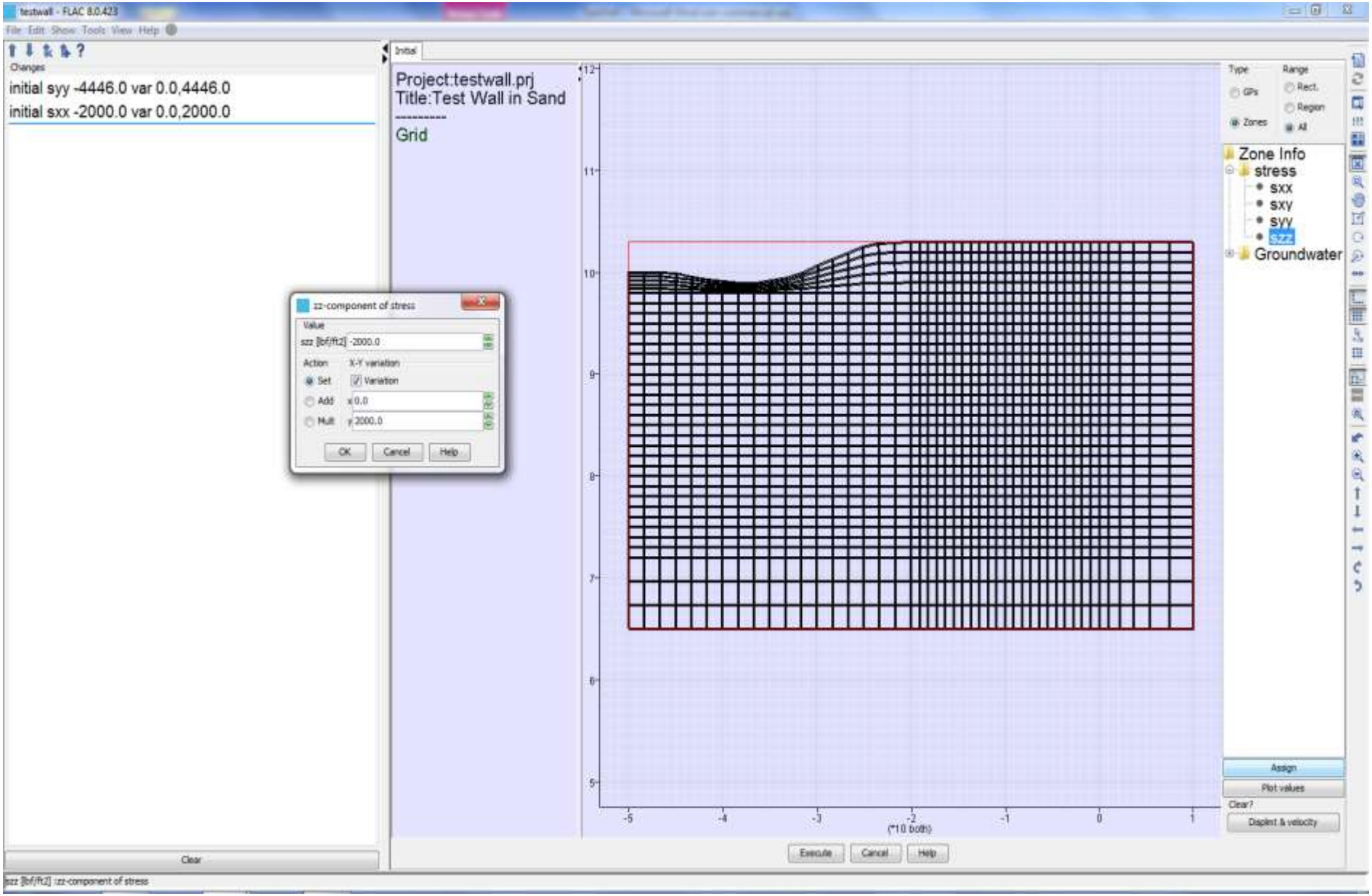
Step 1-6 In the [Materials] edit stage, check [Create] and create the material **sand** with Mohr-Coulomb properties as shown.



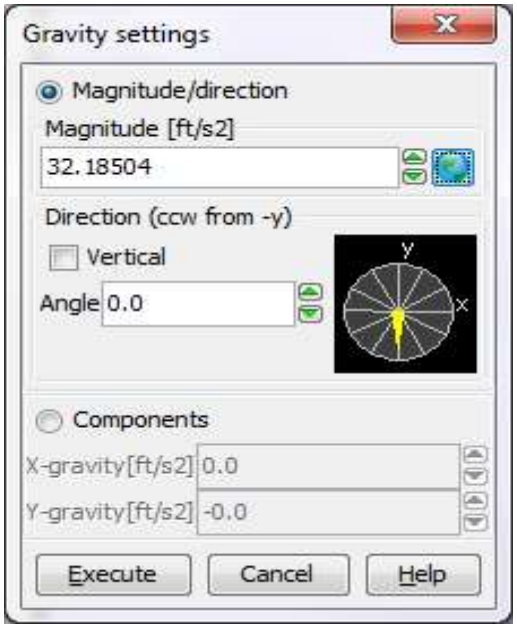
Step 1-7 Press [SetAll] to assign the **sand** material to all zones in the model. Click [OK] to exit the [Edit] tool.

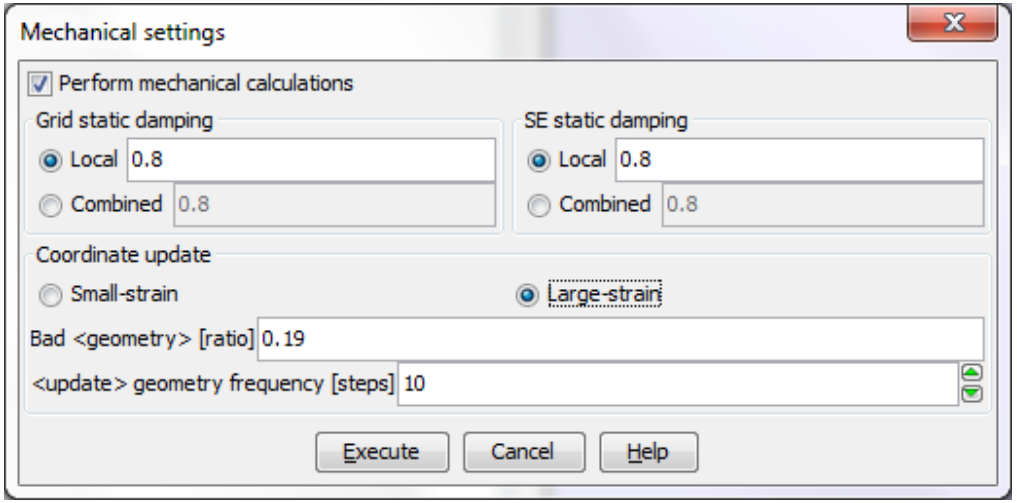


Step 1-8 Press [Execute] to create the commands to send to *FLAC*, and press [Save] to save the model state (testwall1.sav).

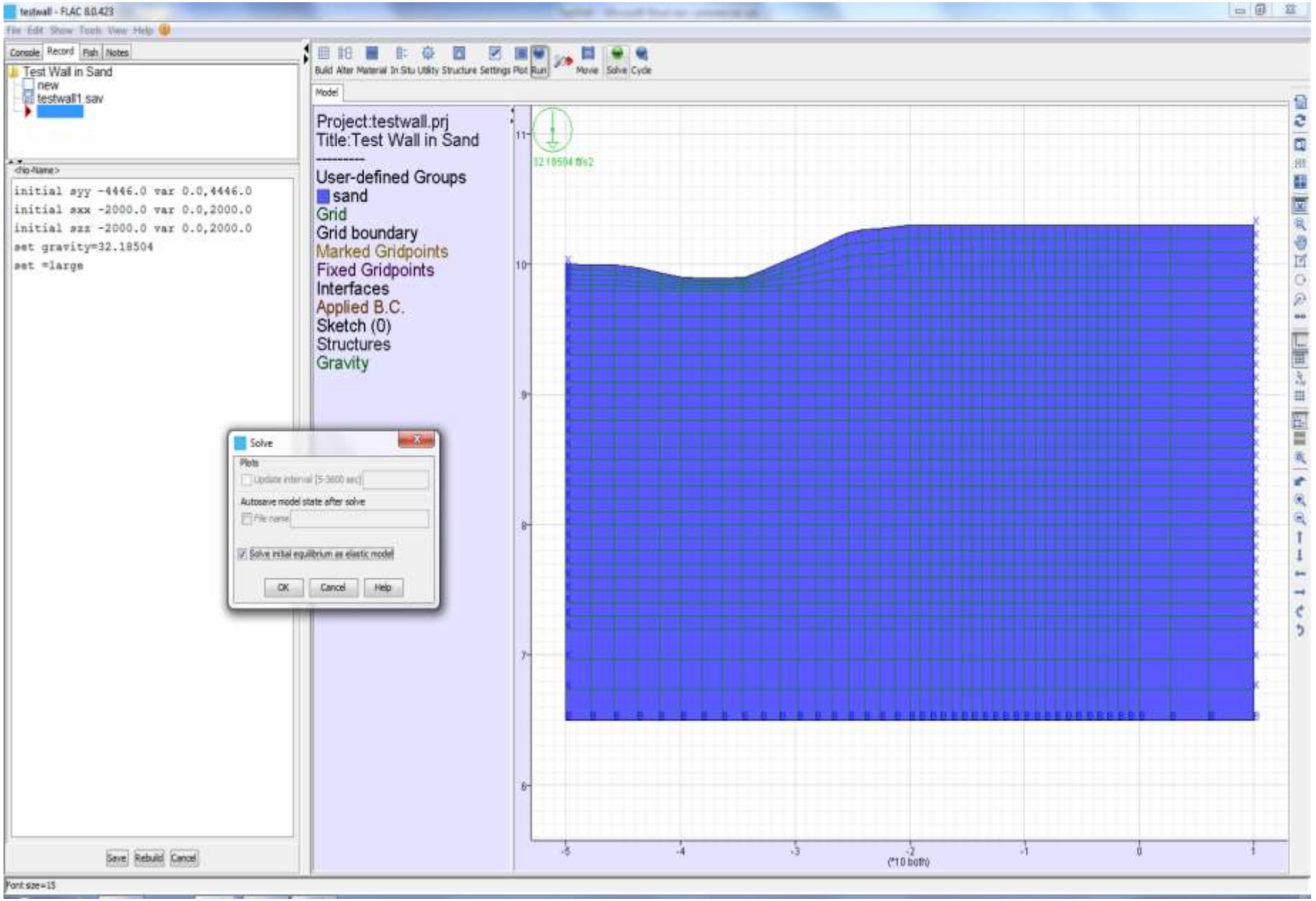


Step 2-1 Initialize the stress state using the [In Situ]/[Initial] tool. The stresses vary linearly from 0.0 at the top of the model to syy = -4446.0, sxx = -2000.0 and szz = -2000.0 at the bottom of the model.

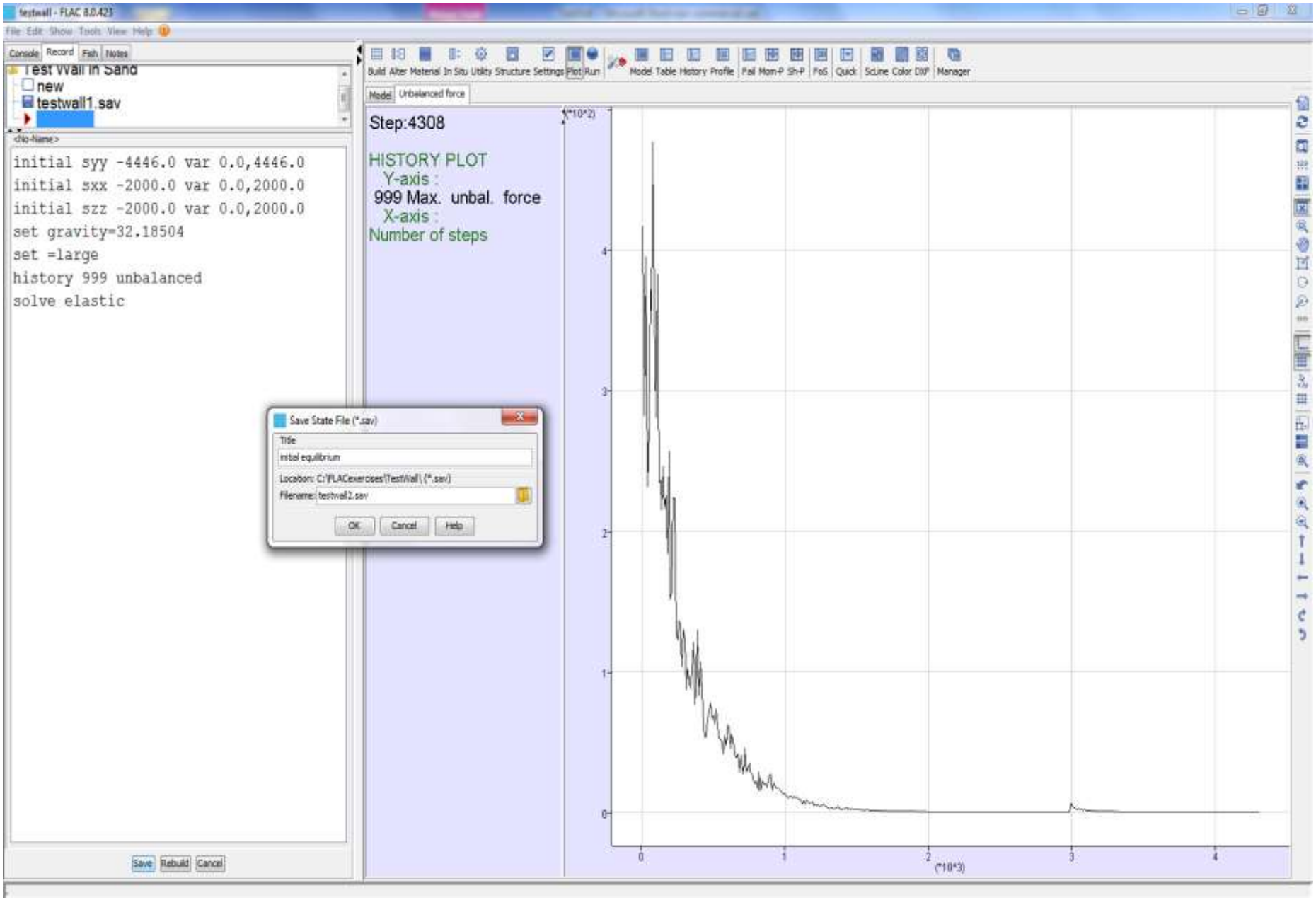




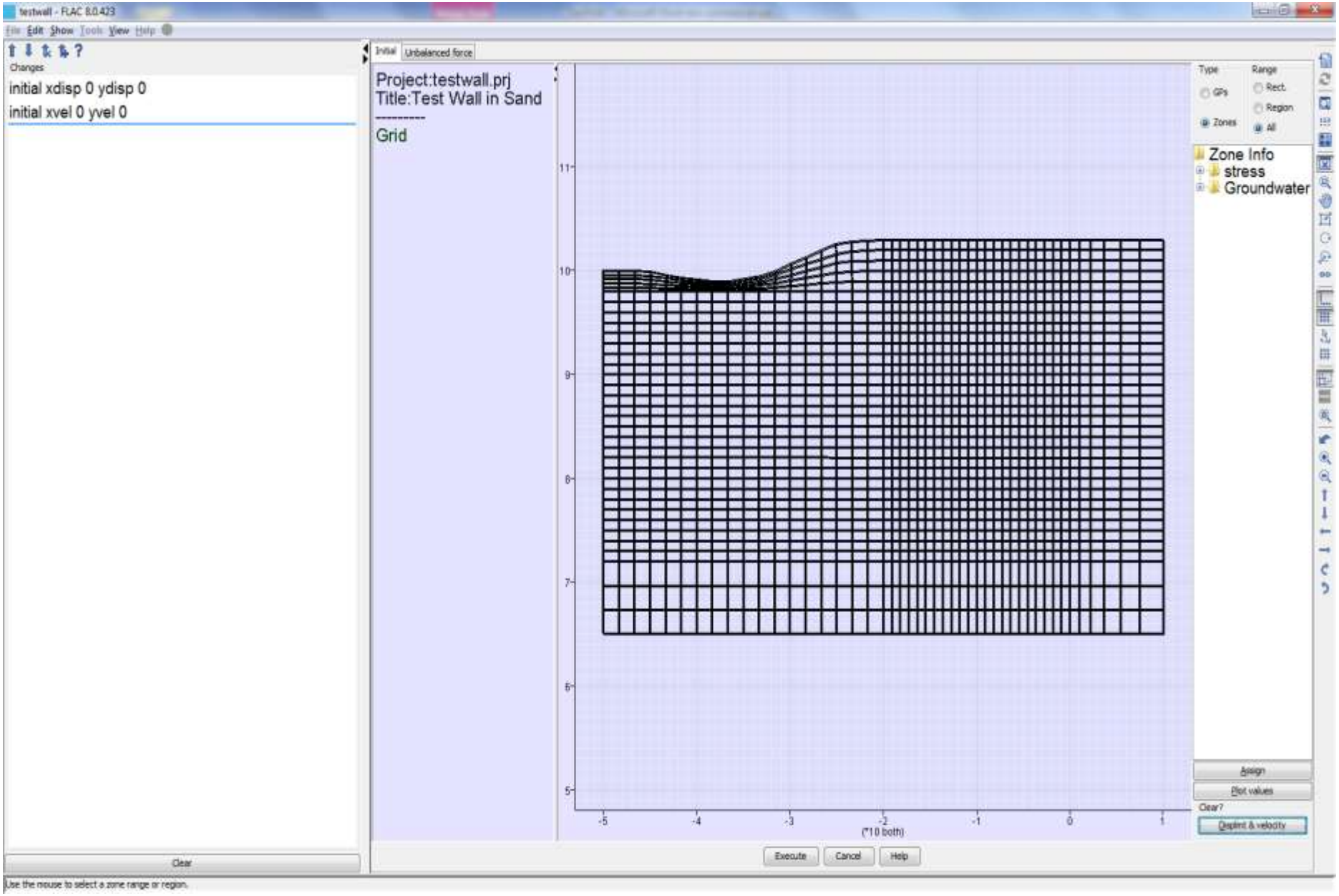
Step 2-2 Assign gravity in the [Settings] /[Gravity] tool, and turn on the large-strain calculation mode in the [Settings]/[Mech] tool.



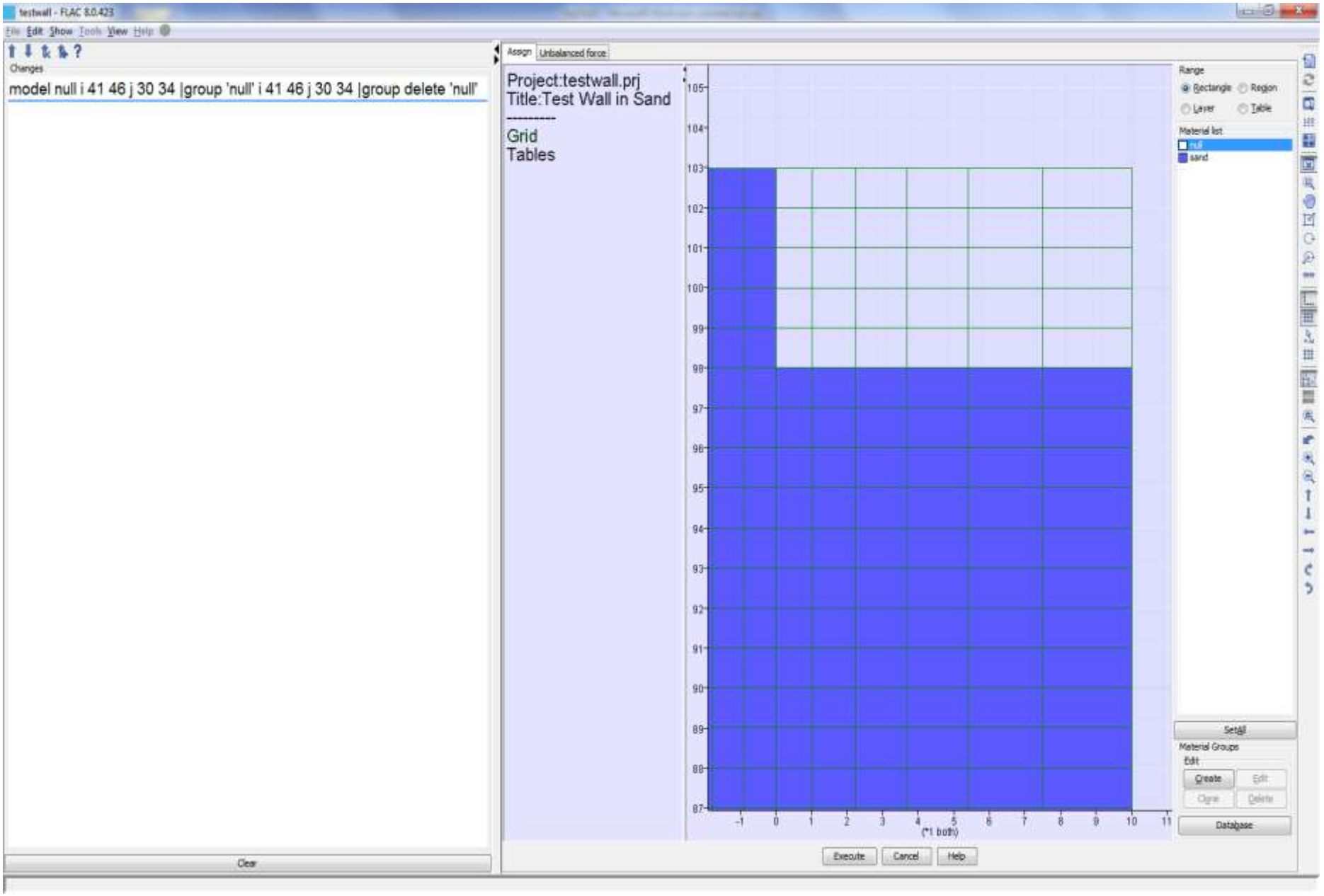
Step 2-3 Solve for the initial equilibrium state using the [Run]/[Solve] tool, with [Solve initial equilibrium as elastic model] checked.



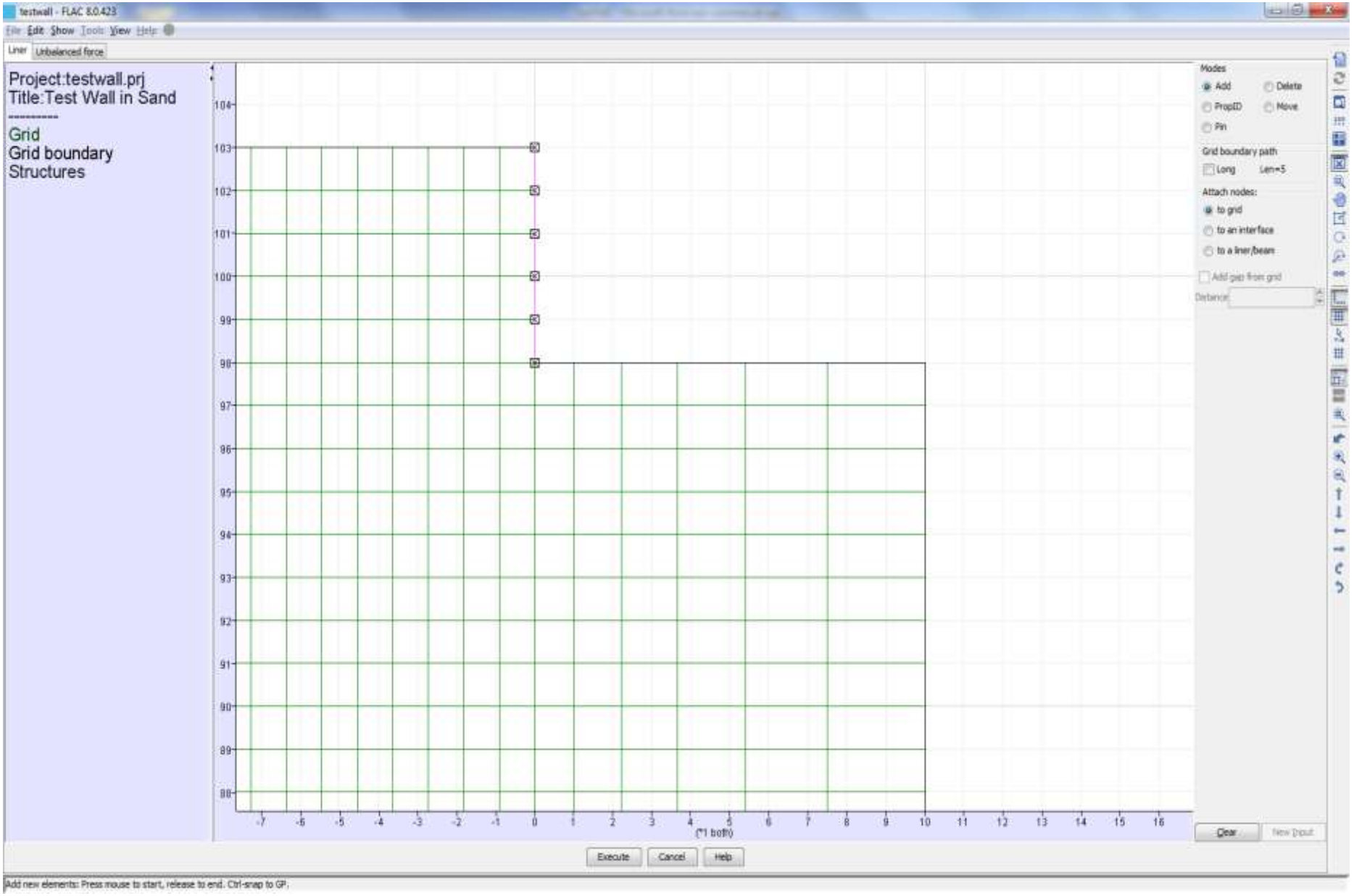
Step 2-4 Plot the maximum unbalanced force history, using the [Plot]/[Quick] tool, to check that equilibrium is reached. Save the state as testwall2.sav.



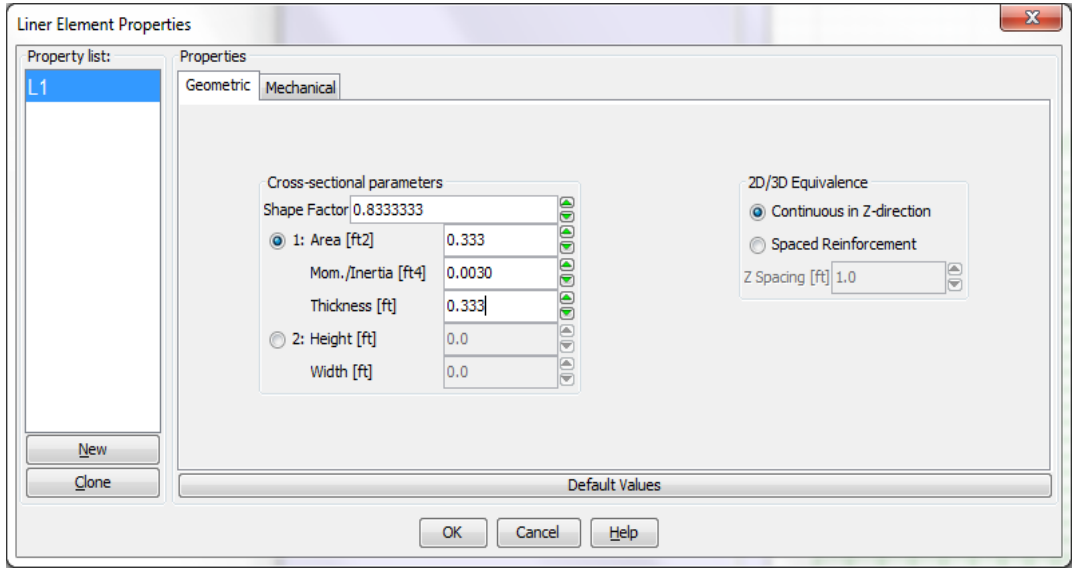
Step 3-1 Initialize displacements to zero in the [In Situ]/[Initial] tool by pressing the Clear? [Displmt & velocity] button. Press [Execute] to send the commands to *FLAC*.

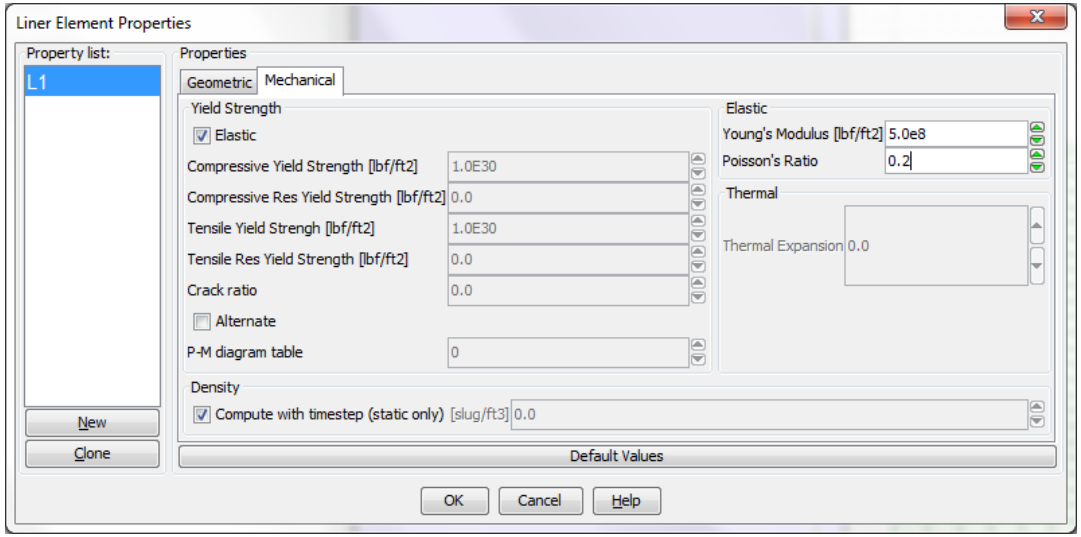


Step 3-2 Stage I excavation – use the [Material]/[Assign] tool and select [null] material to excavate zones to the depth y=98. Press [Execute] to send the commands to *FLAC*.

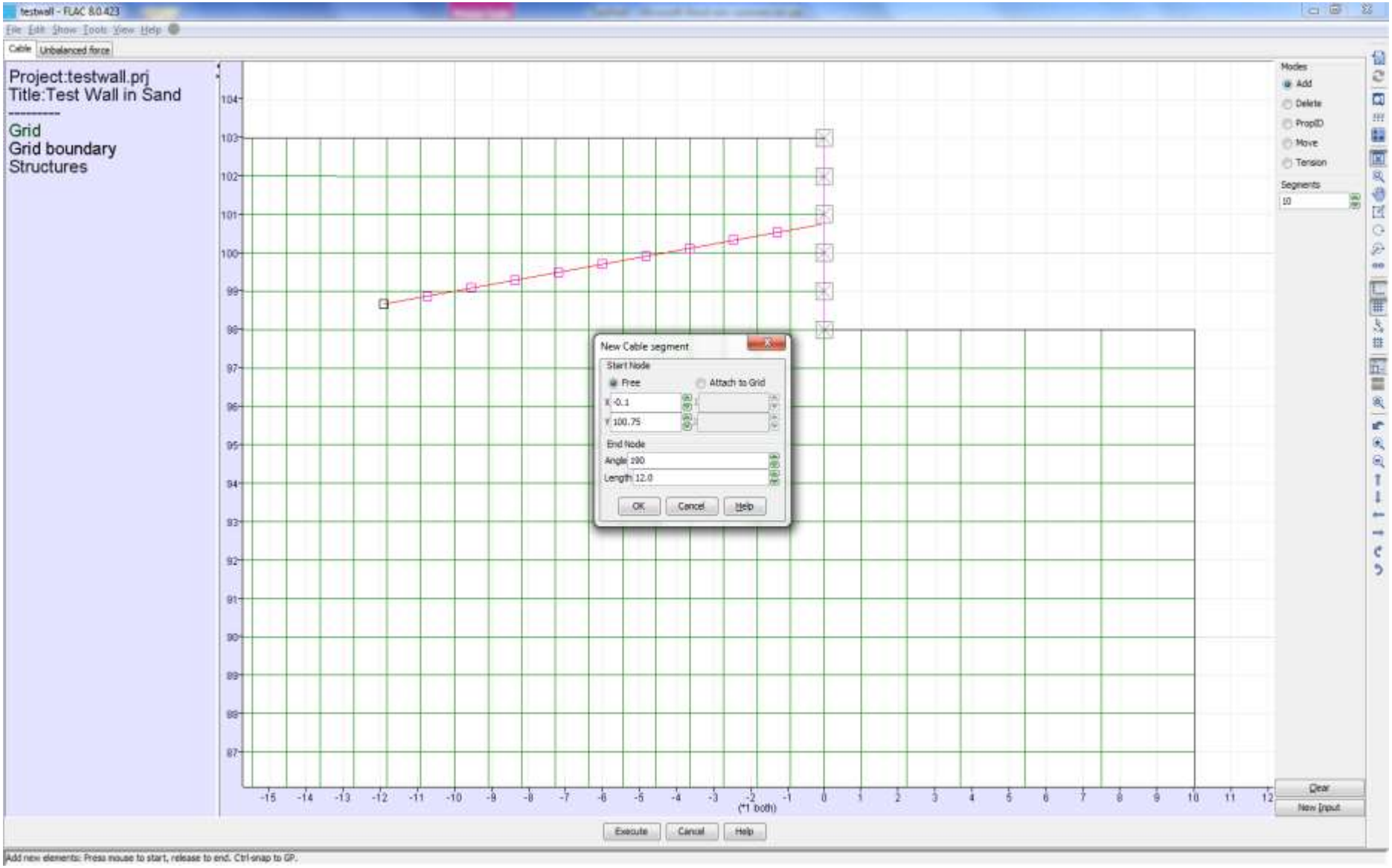


Step 3-3 In the [Structure]/[Liner] tool, check [Add] and drag the mouse along the boundary as shown to attach liner nodes to gridpoints in the excavation region. Press [Execute] to send the commands to *FLAC*.

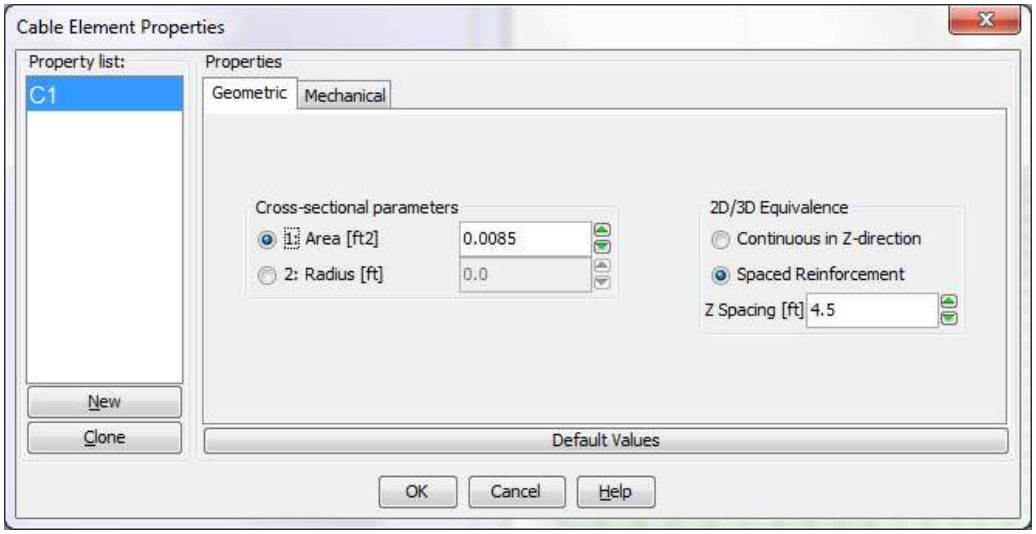


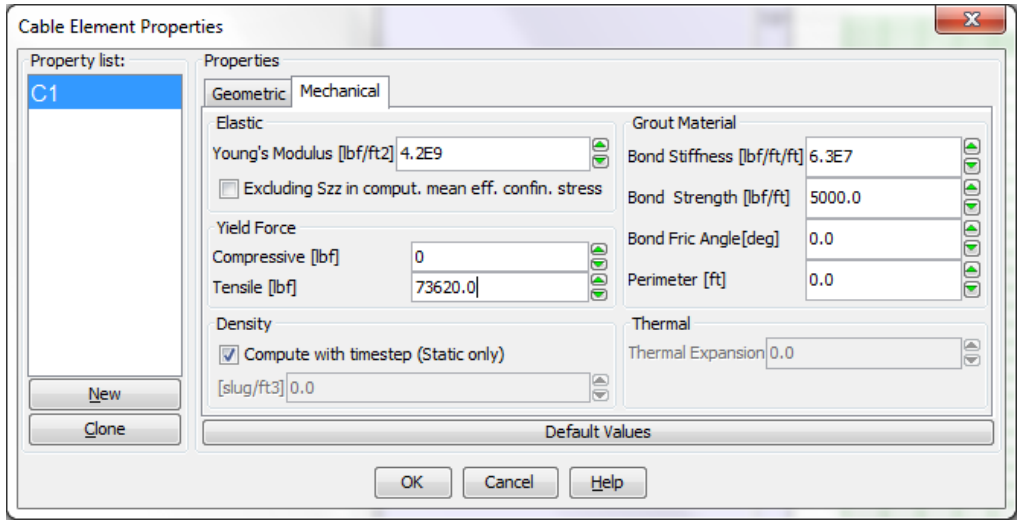


Step 3-4 In the [Structure]/[SEProp] tool, assign liner properties as shown.

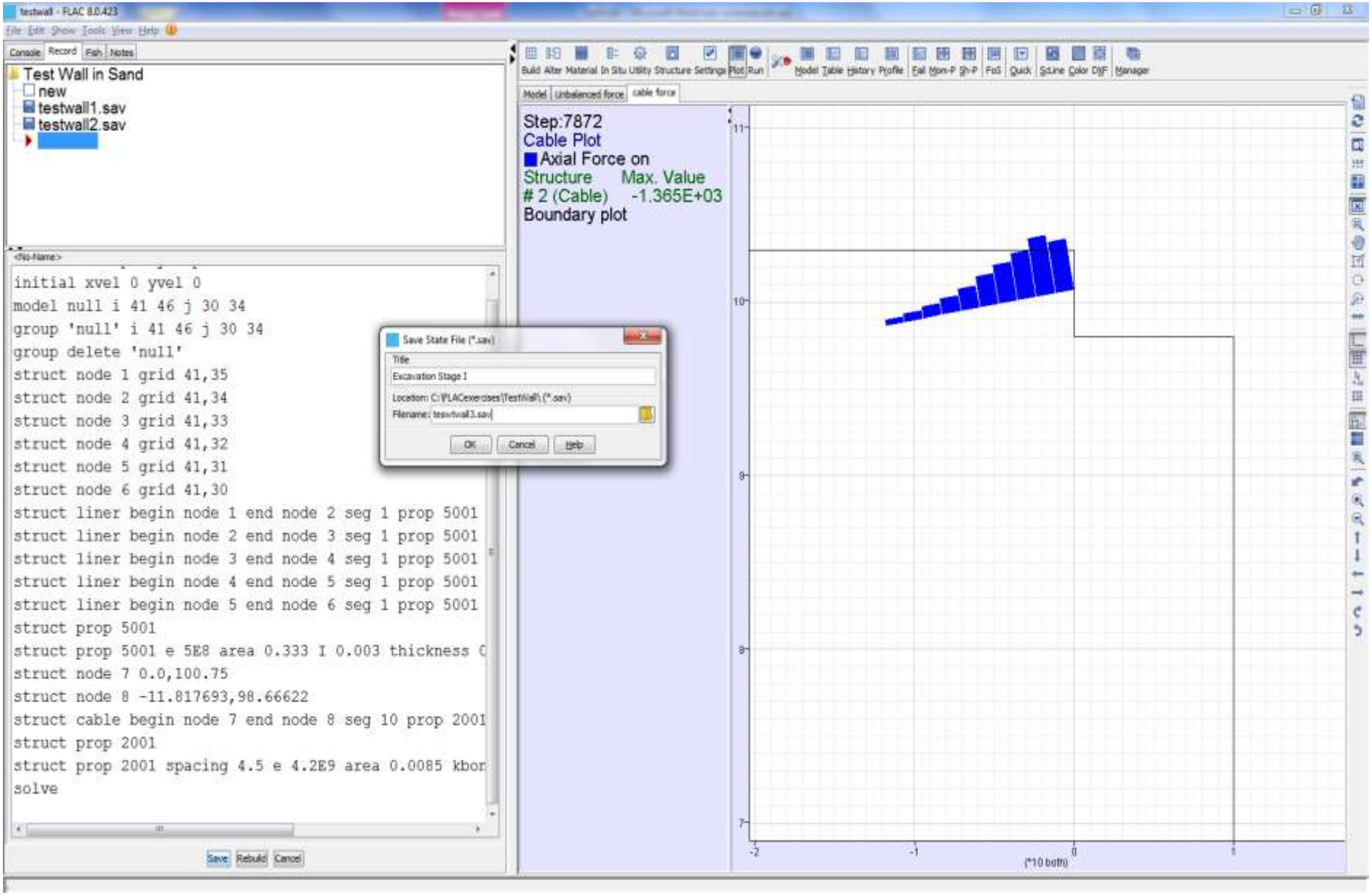


Step 3-5 In the [Structure]/[Cable] tool, check [Add], select 10 segments, and left click the mouse at a point inside the grid. This opens a *New Cable segment* dialog. Input a starting point at x=-0.1, y=100.75, and specify an angle of 190^{o} and length of 12.0. The cable, composed of 10 segments, is created as shown. Press [Execute] to send the commands to *FLAC*.

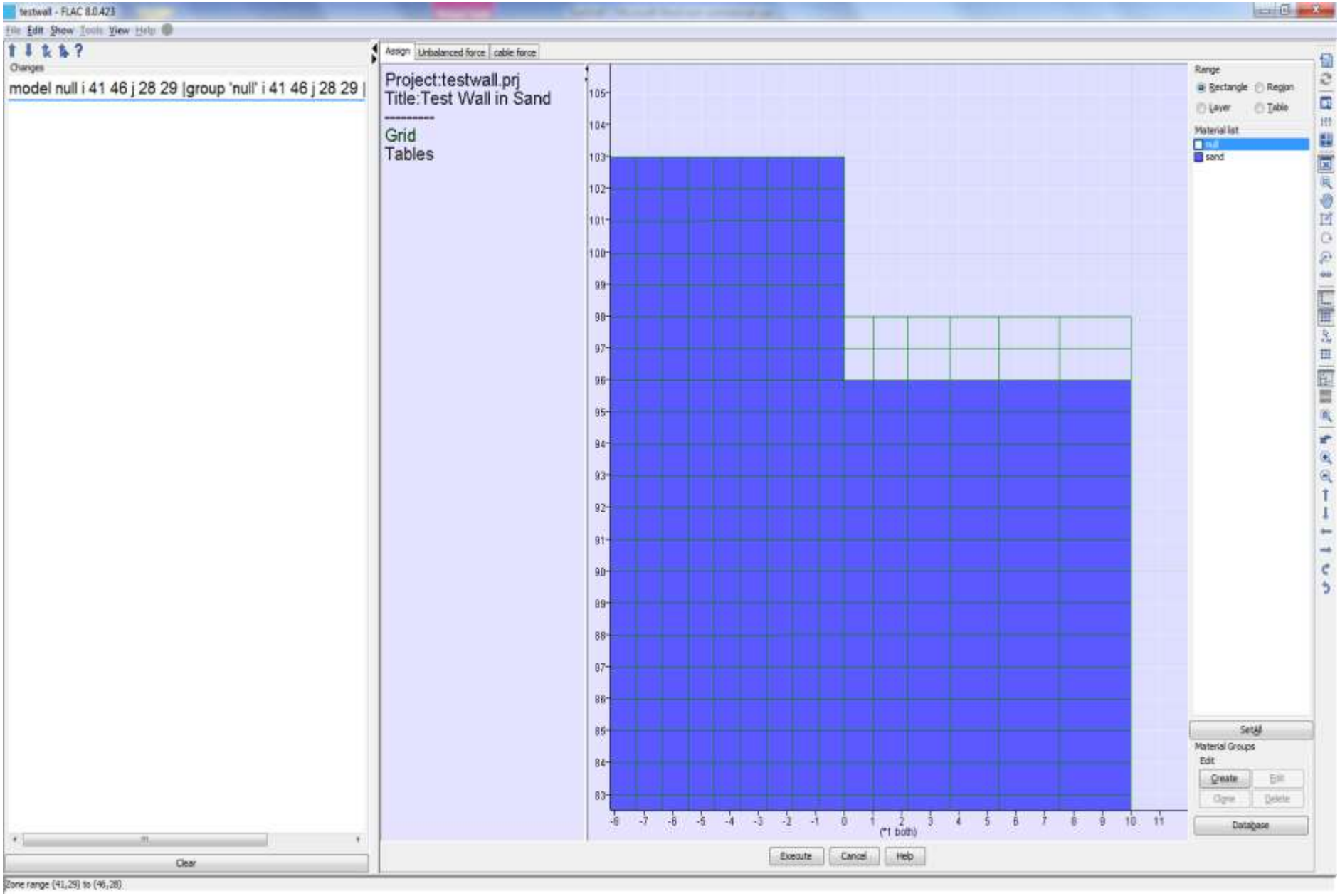




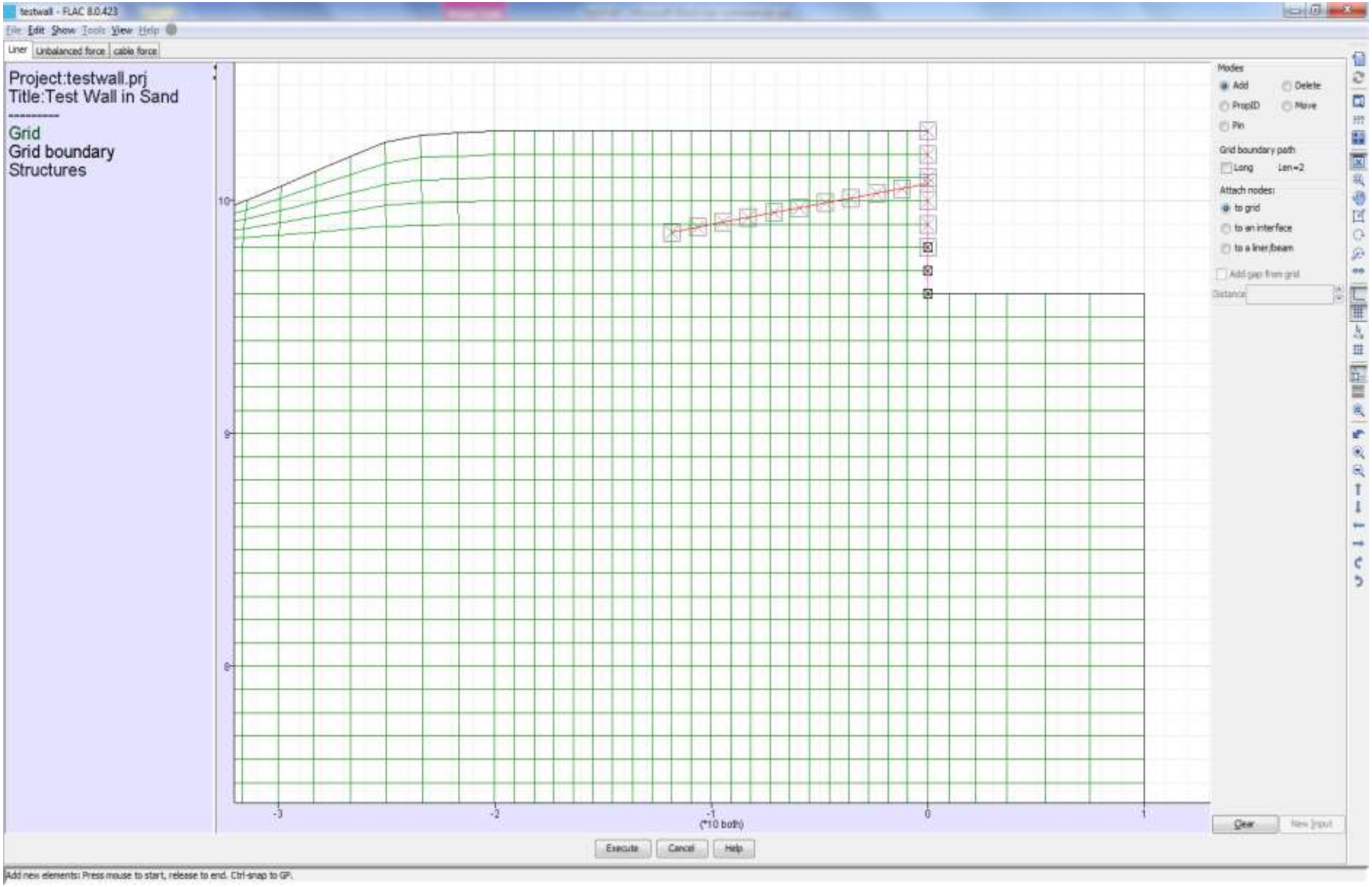
Step 3-6 In the [Structure]/[SEProp] tool, assign cable properties as shown. Note that cable spacing for the Row 1 cables is 4.5 ft.



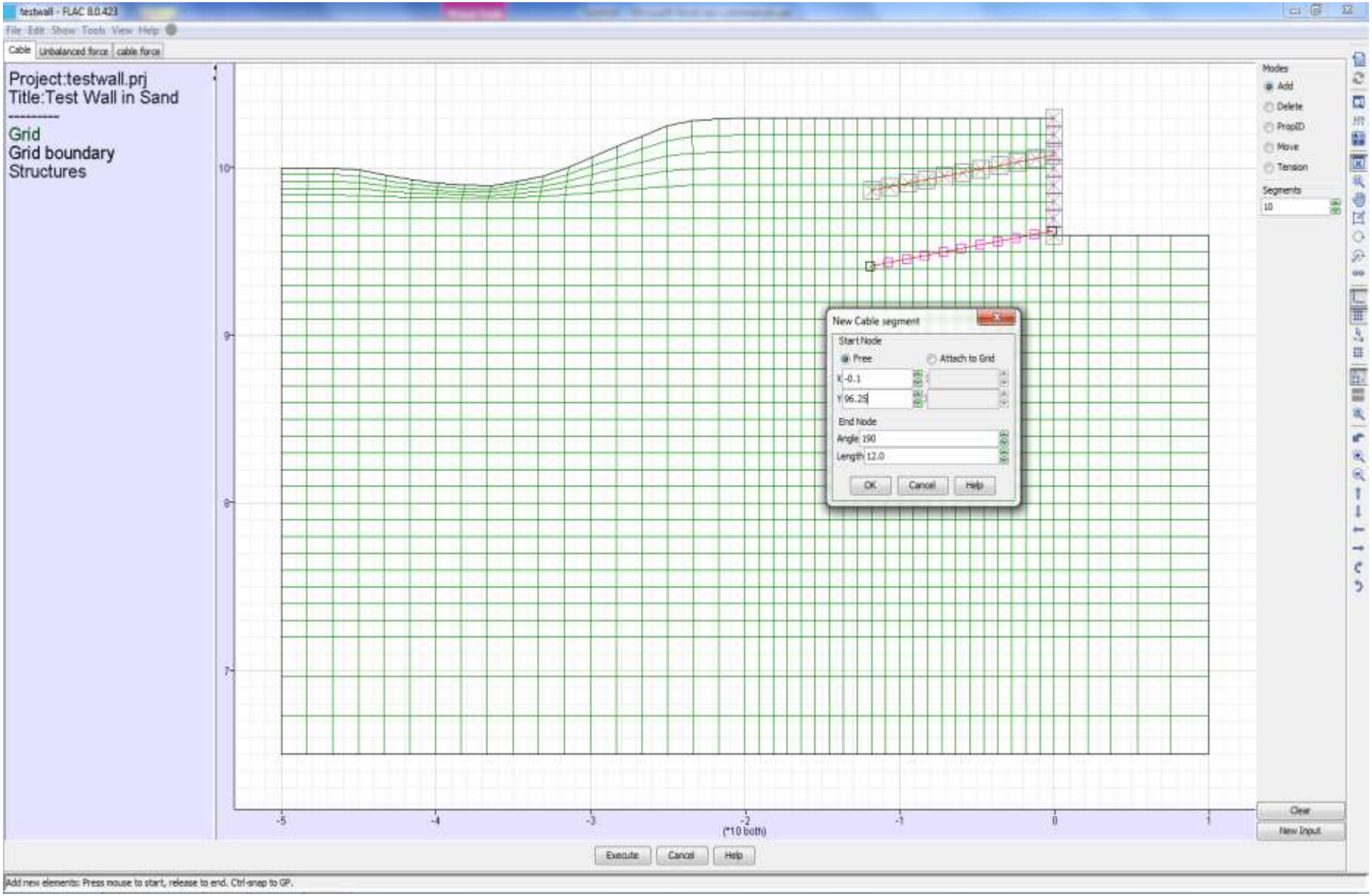
Step 3-7 Solve for the equilibrium state using the [Run]/[Solve] tool. Plot cable forces in the [Plot]/[Model] tool. Press [Save] to save the state as testwall3.sav.



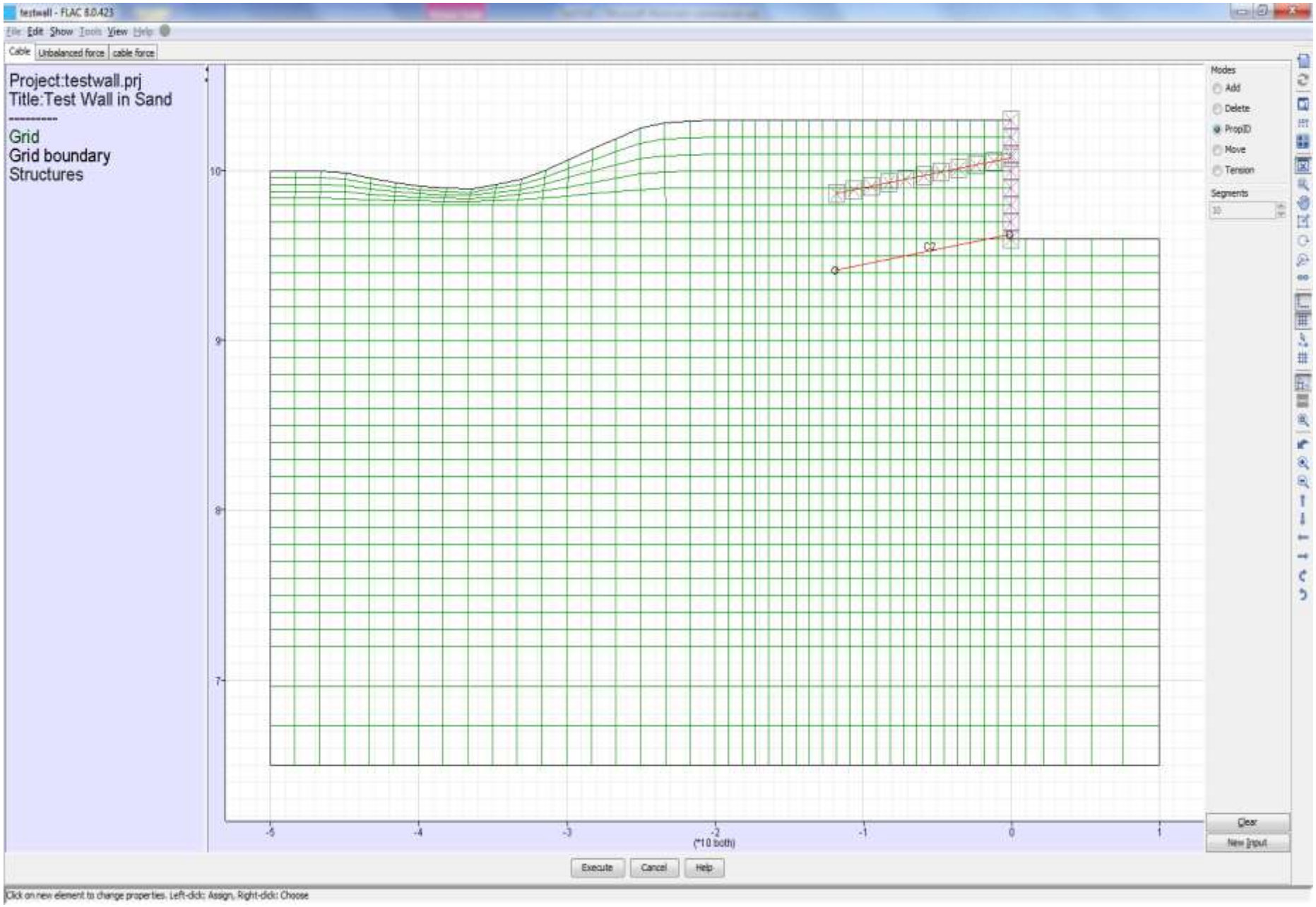
Step 4-1 Stage II excavation – use the [Material]/[Assign] tool and select [null] material to excavate zones to the depth y=96.



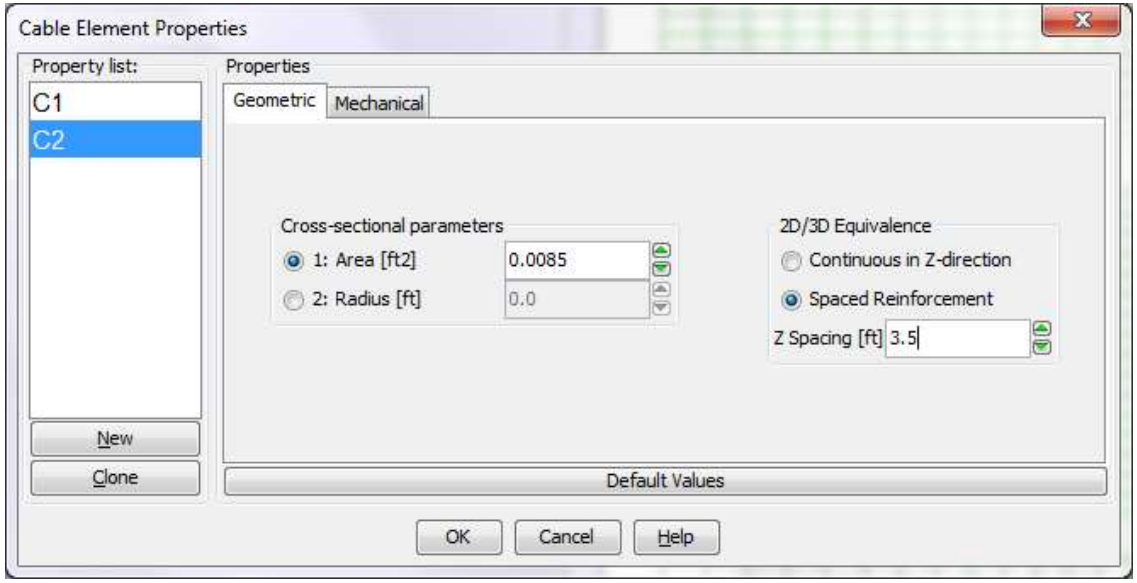
Step 4-2 In the [Structure]/[Liner] tool, check [Add] and drag the mouse along the boundary as shown to attach liner nodes to gridpoints in the excavation region. Press [Execute] to send the commands to *FLAC*

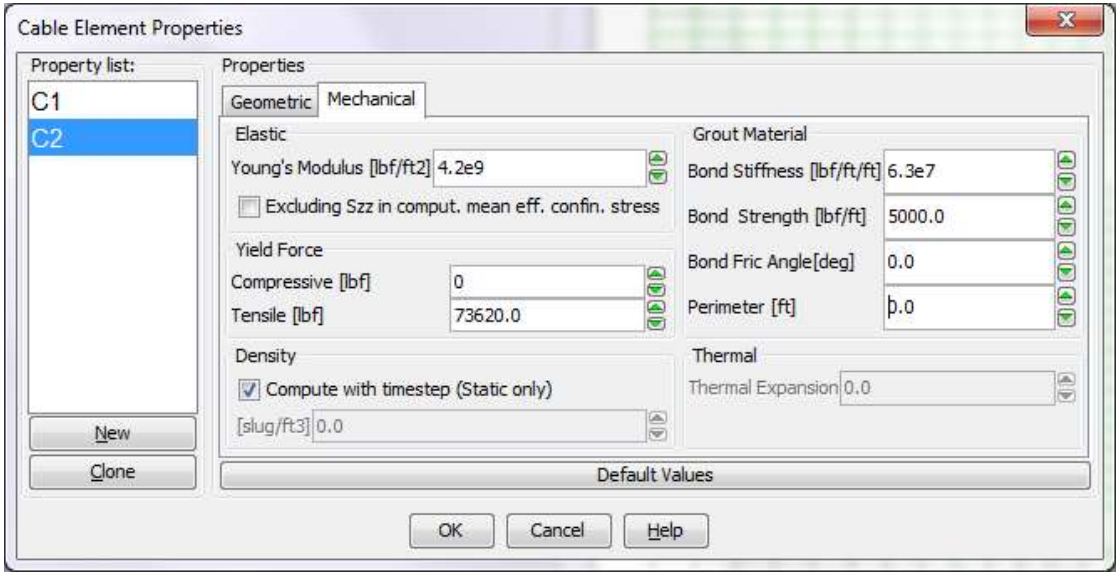


Step 4-3 In the [Structure]/[Cable] tool, check [Add], select 10 segments, and left click the mouse at a point inside the grid. This opens a *New Cable segment* dialog. Input a starting point at x=-0.1, y=96.25, and specify an angle of 190^{o} and length of 12.0. The cable, composed of 10 segments, is created as shown.

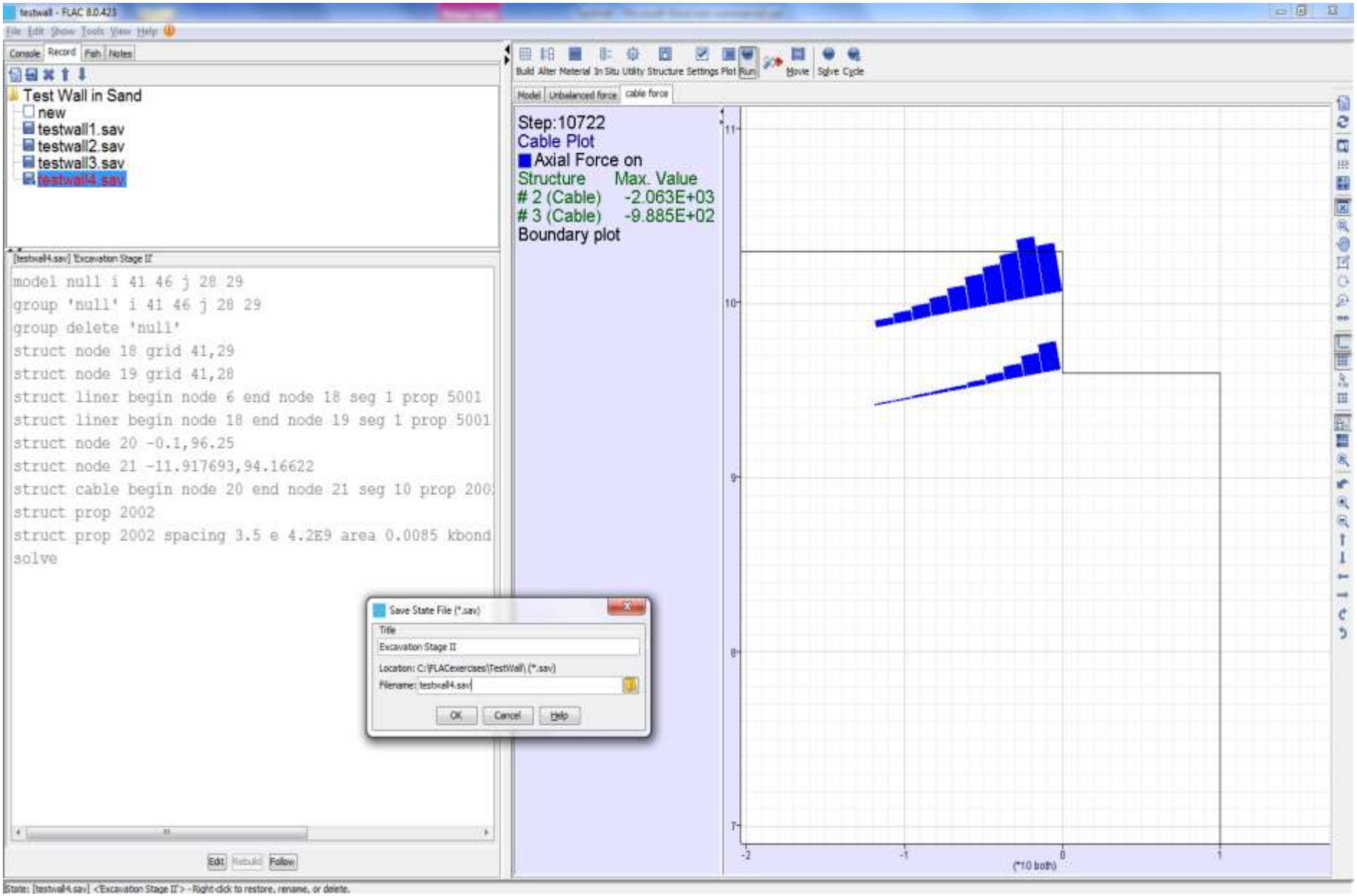


Step 4-4 Press [PropID] to change the property ID number for the new cable. Press [Execute] to send the commands to FLAC.

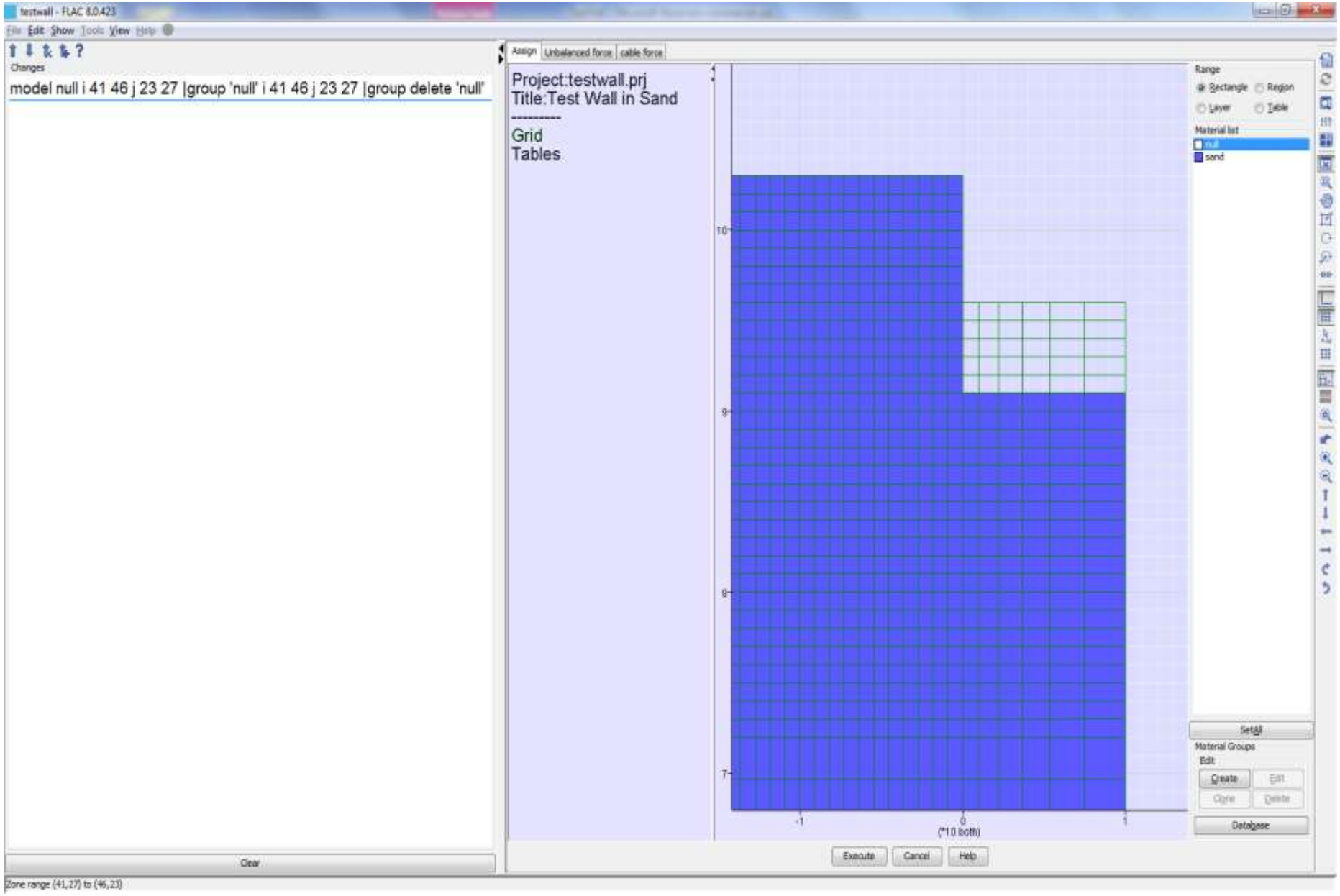




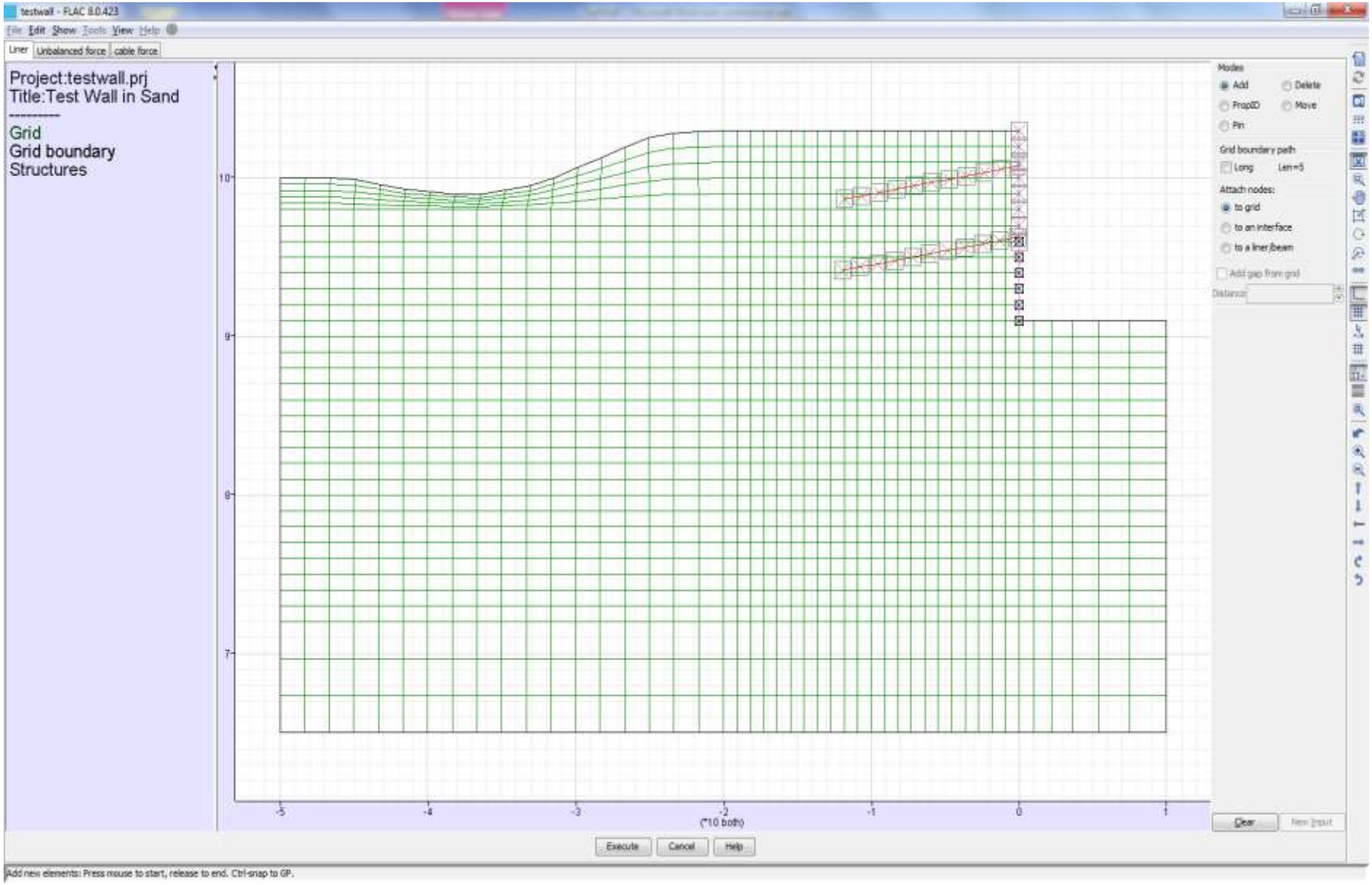
Step 4-5 In the [Structure]/[SEProp] tool, assign cable properties as shown. Note that cable spacing for the Row 2 cables is 3.5 ft.



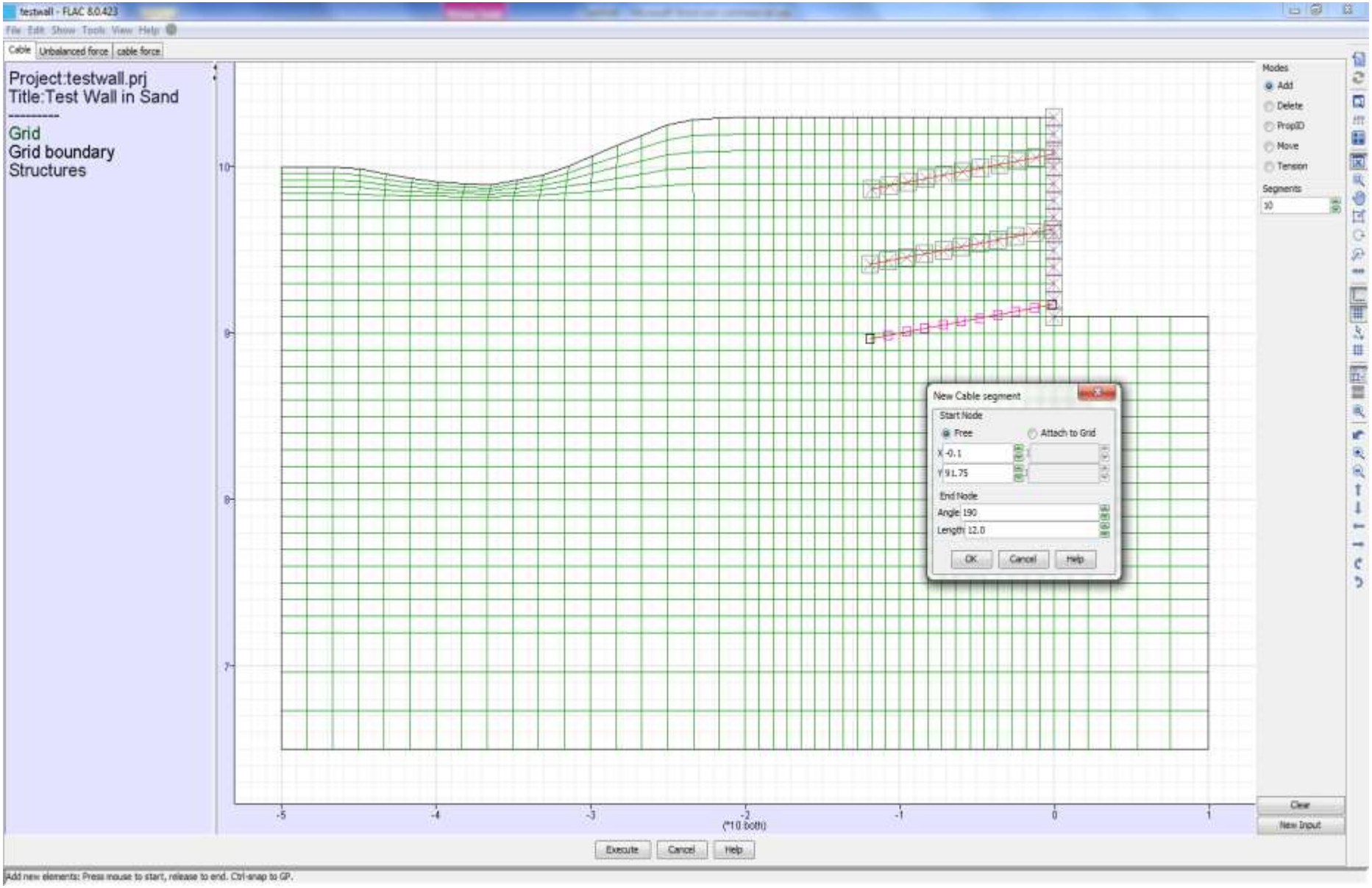
Step 4-6 Solve for the equilibrium state using the [Run]/[Solve] tool. Plot cable forces in the [Plot]/[Model] tool. Press [Save] to save the state as testwall4.sav.



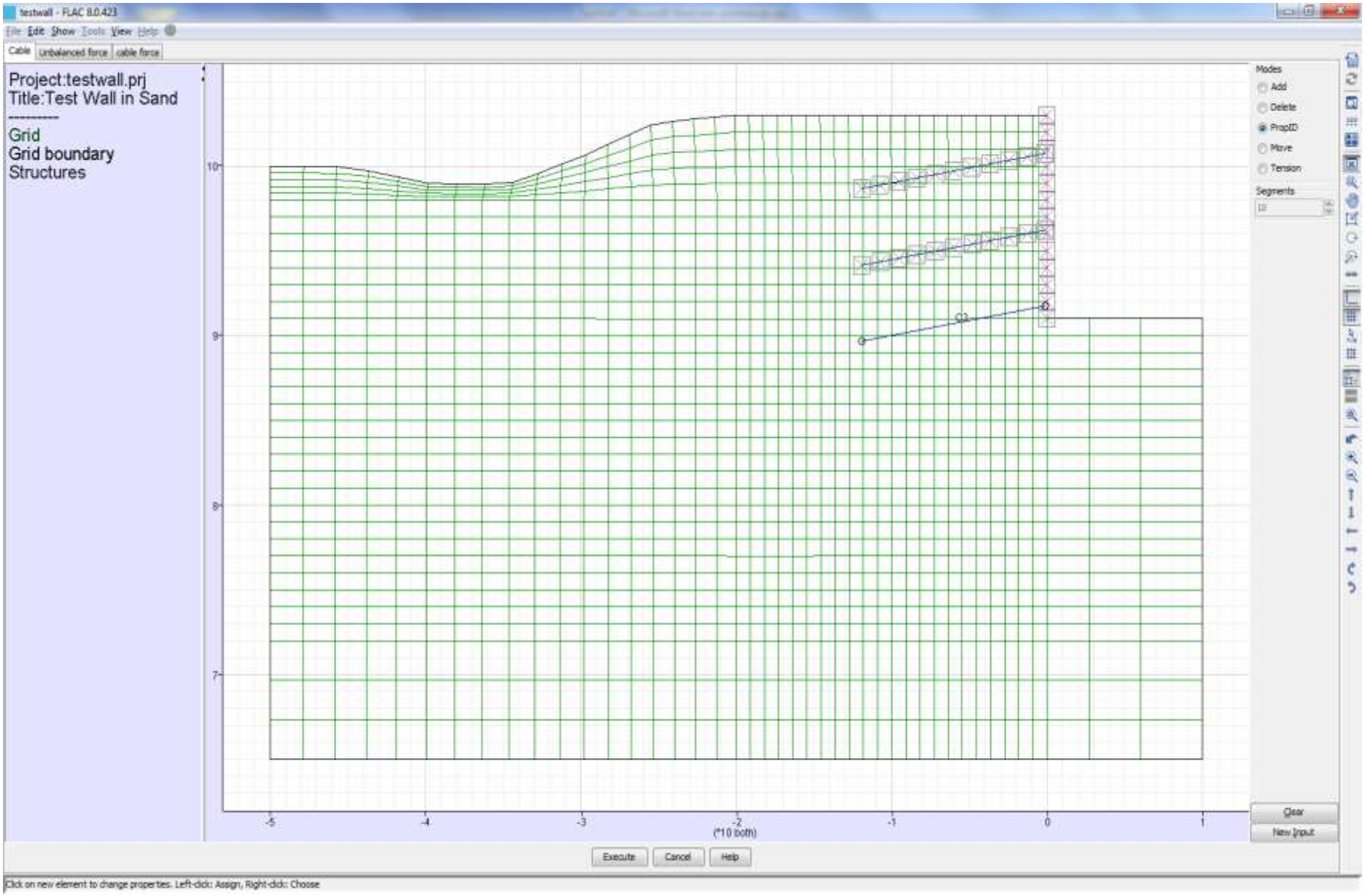
Step 5-1 Stage III excavation – use the [Material]/[Assign] tool and select [null] material to excavate zones to the depth y=91.



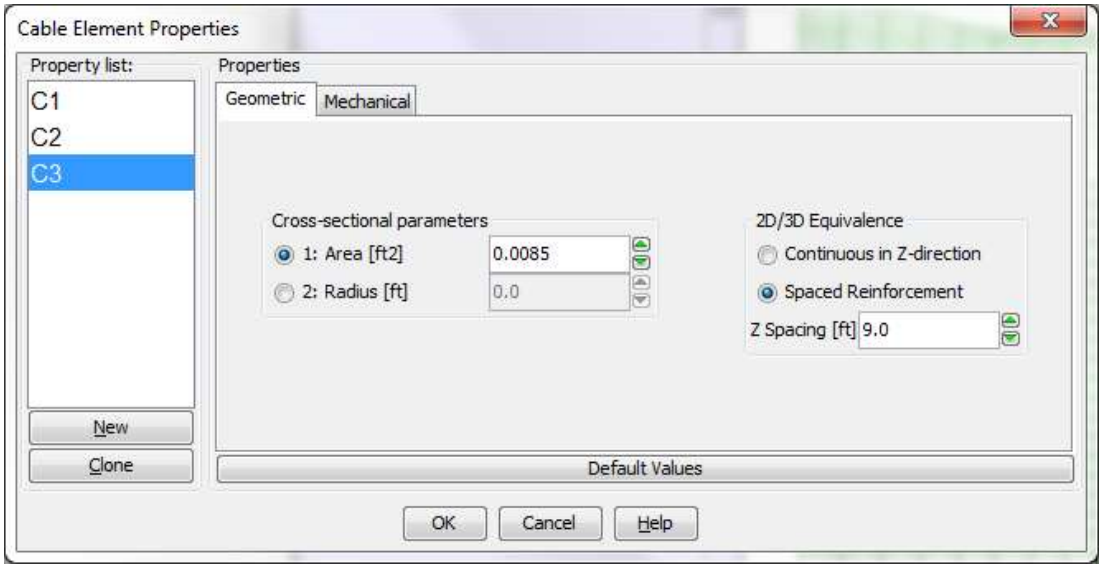
Step 5-2 In the [Structure]/[Liner] tool, check [Add] and drag the mouse along the boundary as shown to attach liner nodes to gridpoints in the excavation region. Press [Execute] to send the commands to *FLAC*

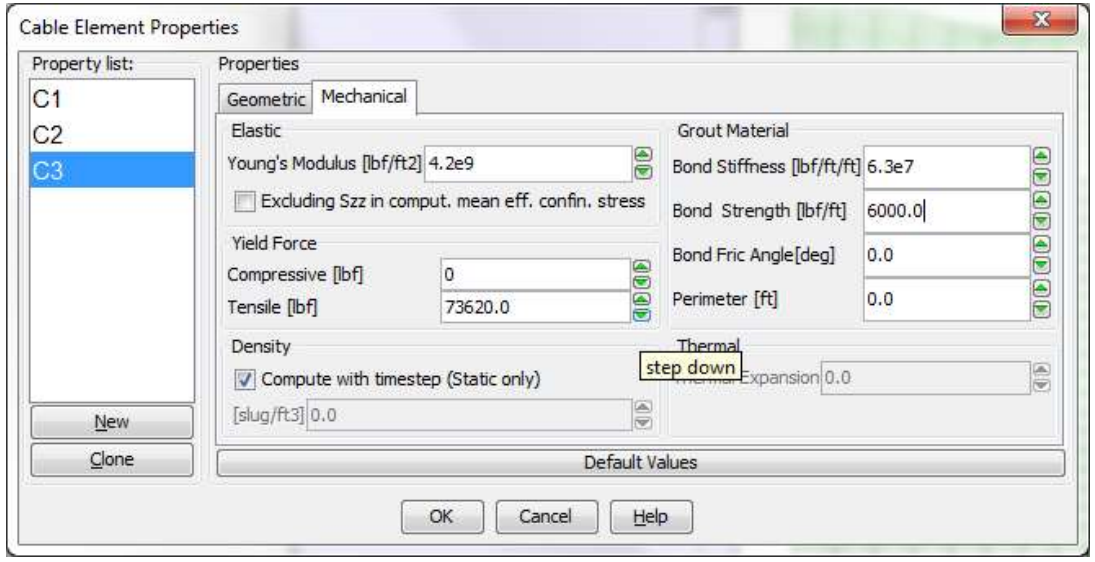


Step 5-3 In the [Structure]/[Cable] tool, check [Add], select 10 segments, and left click the mouse at a point inside the grid. This opens a *New Cable segment* dialog. Input a starting point at x=-0.1, y=91.25, and specify an angle of 190^{o} and length of 12.0. The cable, composed of 10 segments, is created as shown.

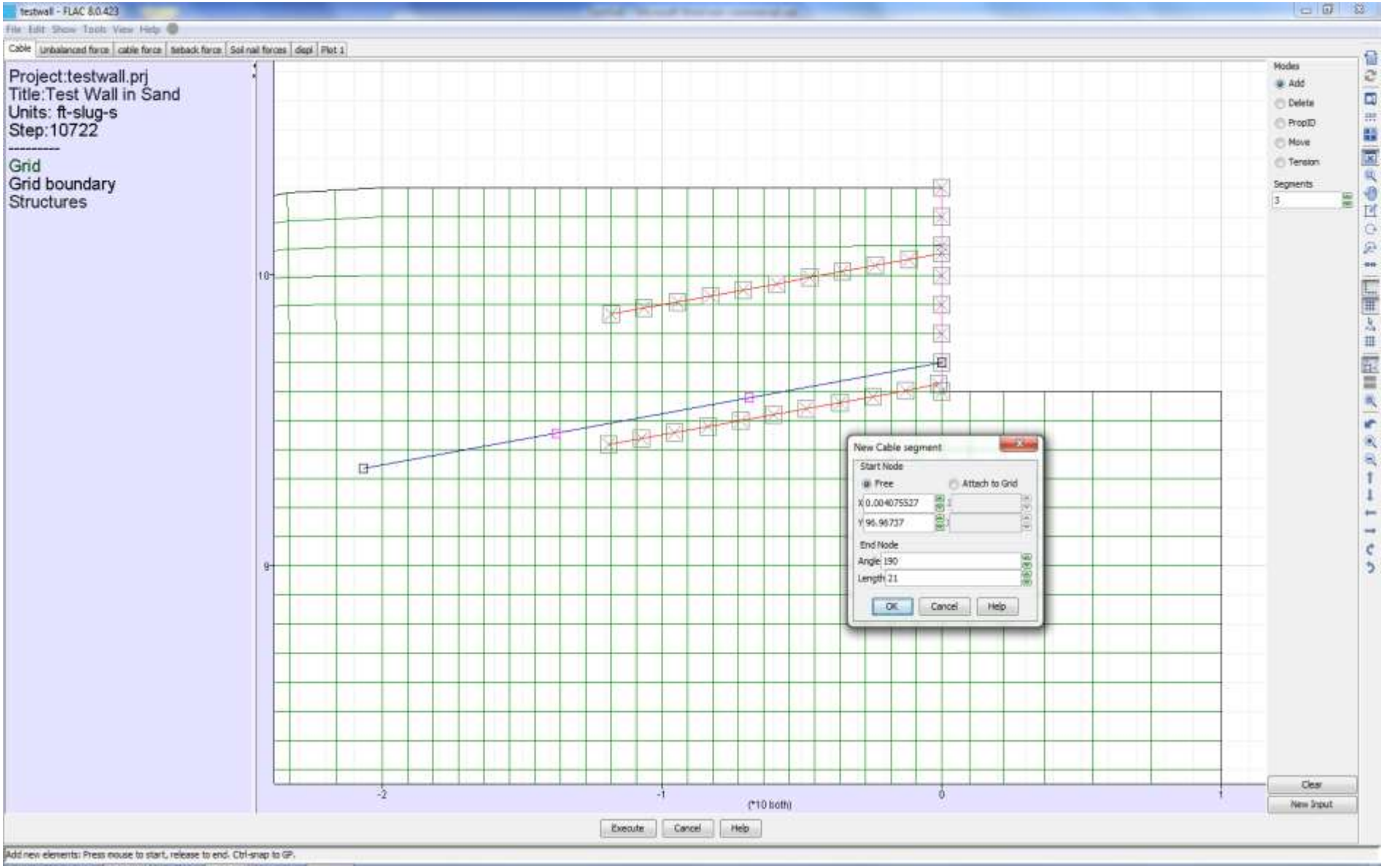


Step 5-4 Press [PropID] to change the property ID number for the new cable. Press [Execute] to send the commands to FLAC.

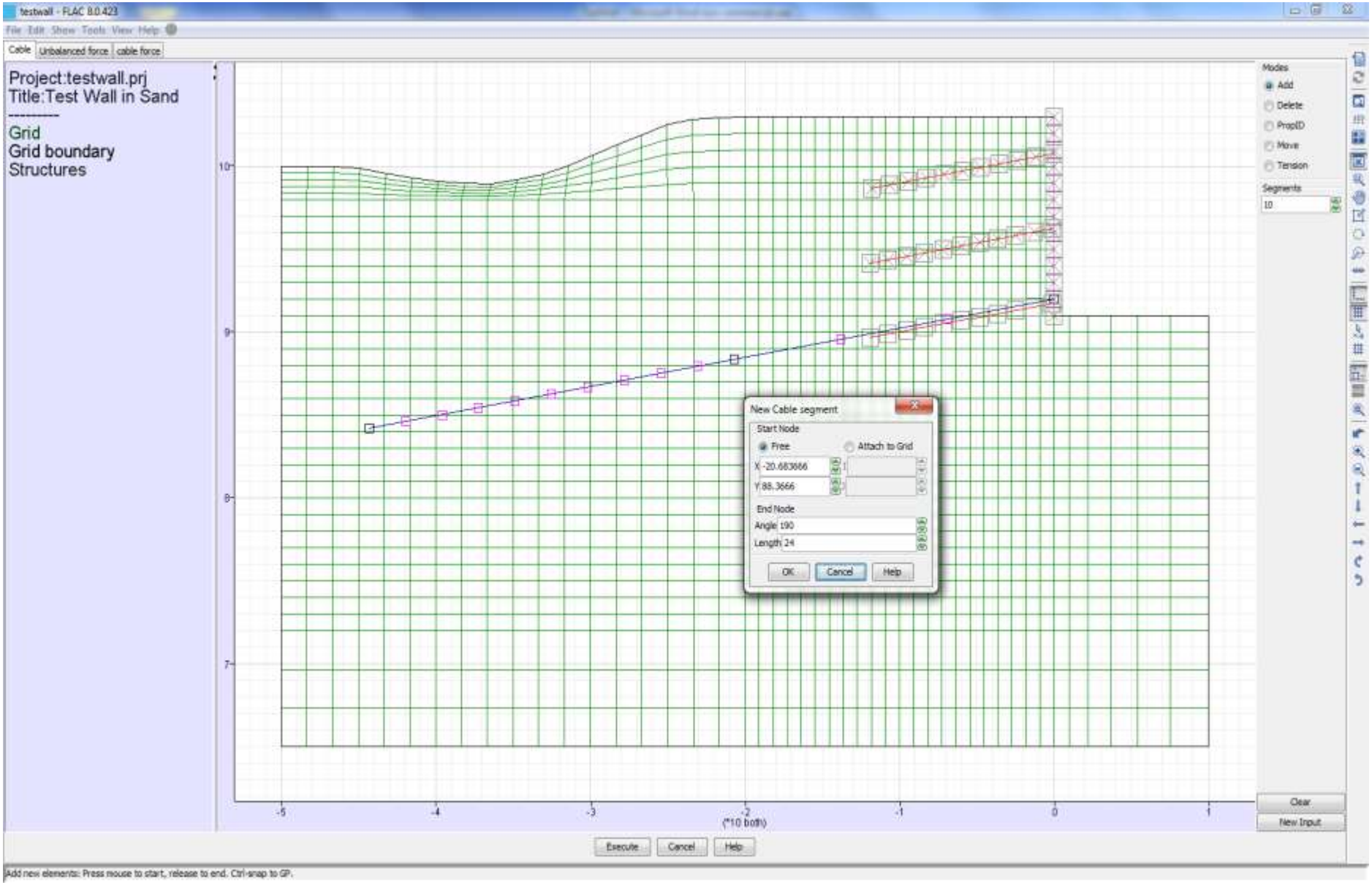




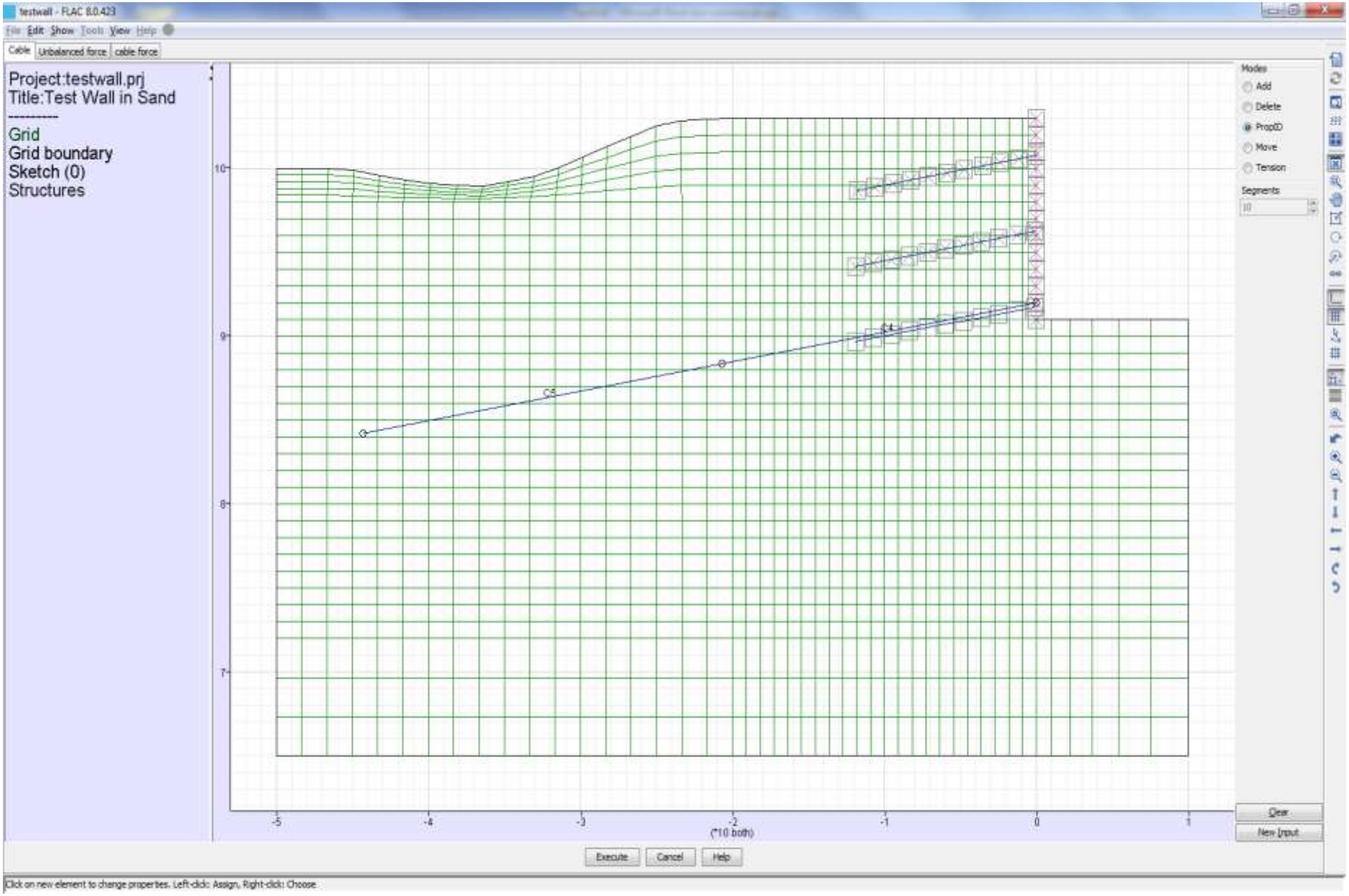
Step 5-5 In the [Structure]/[SEProp] tool, assign cable properties as shown. Note that cable spacing for the Row 3 cables is 9 ft. Press [OK] to send the commands to *FLAC*.



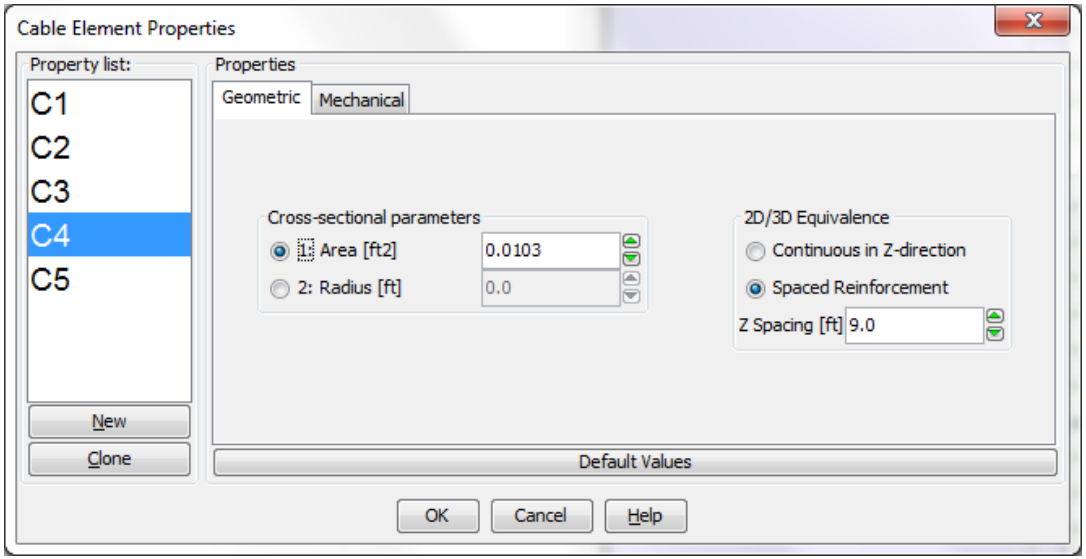
Step 5-6 In the [Structures]/[Cables] tool, check [Add], select 3 segments, and left click the mouse directly on the shotcrete liner node, as shown above. This opens a New Cable segment dialog. The starting point for the ungrouted portion of the tieback will be connected to the shotcrete liner. The tieback angle is 190^{o} and the ungrouted length is 21 ft.

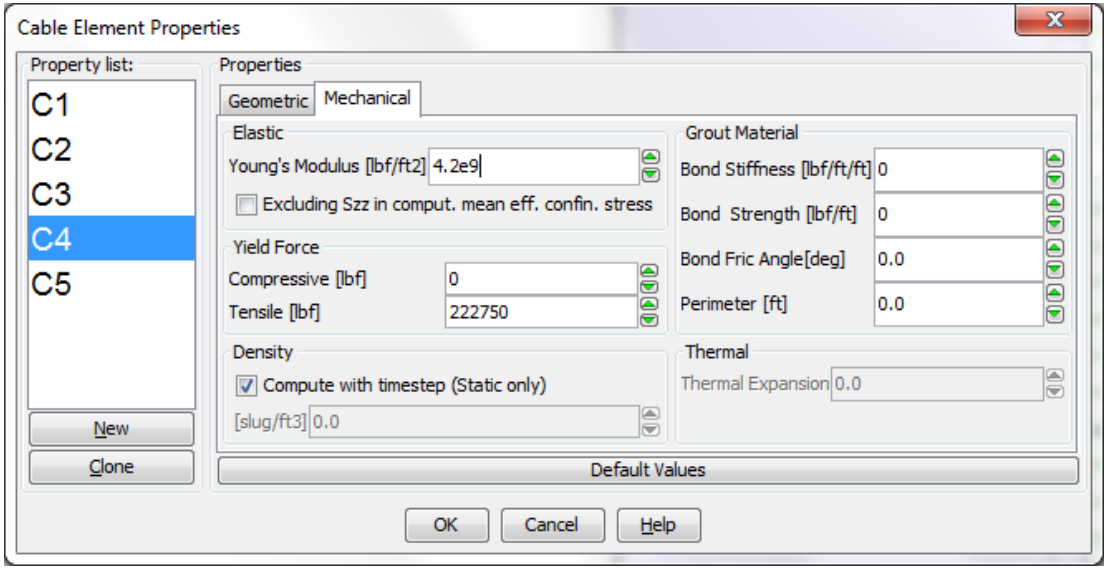


Step 5-7 In the [Structures]/[Cables] tool, check [Add], select 10 segments, and left click the mouse on the ending node of the ungrouted portion of the tieback. When the *New Cable segment* dialog opens, check [Free] and specify an angle of 190^{o} and length of 24 ft. The grouted portion of the tieback is created.

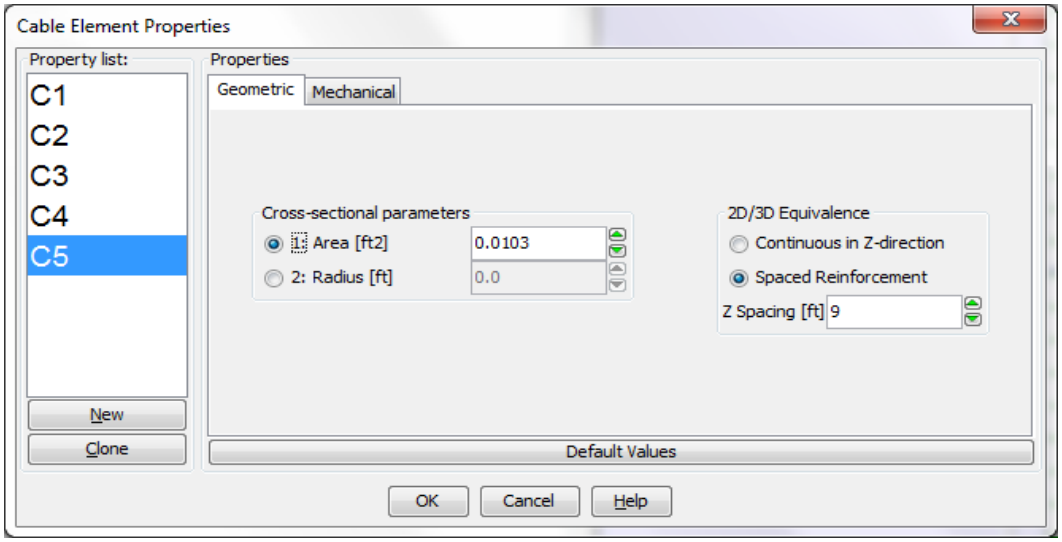


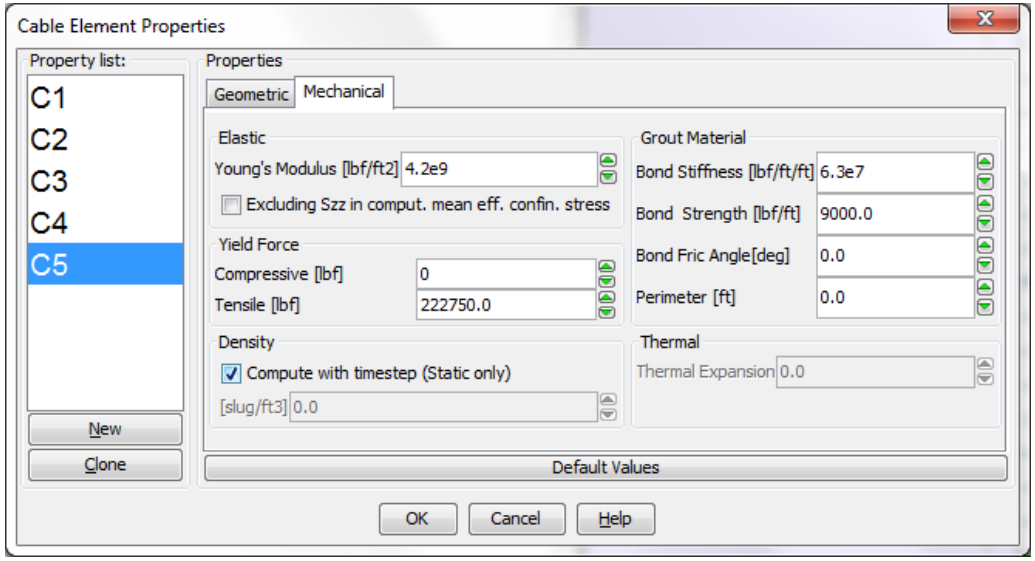
Step 5-8 Press [PropID] to change the property ID number for the tieback. The ungrouted portion and grouted portion are assigned different property ID numbers. Press [Execute] to send the commands to *FLAC*.



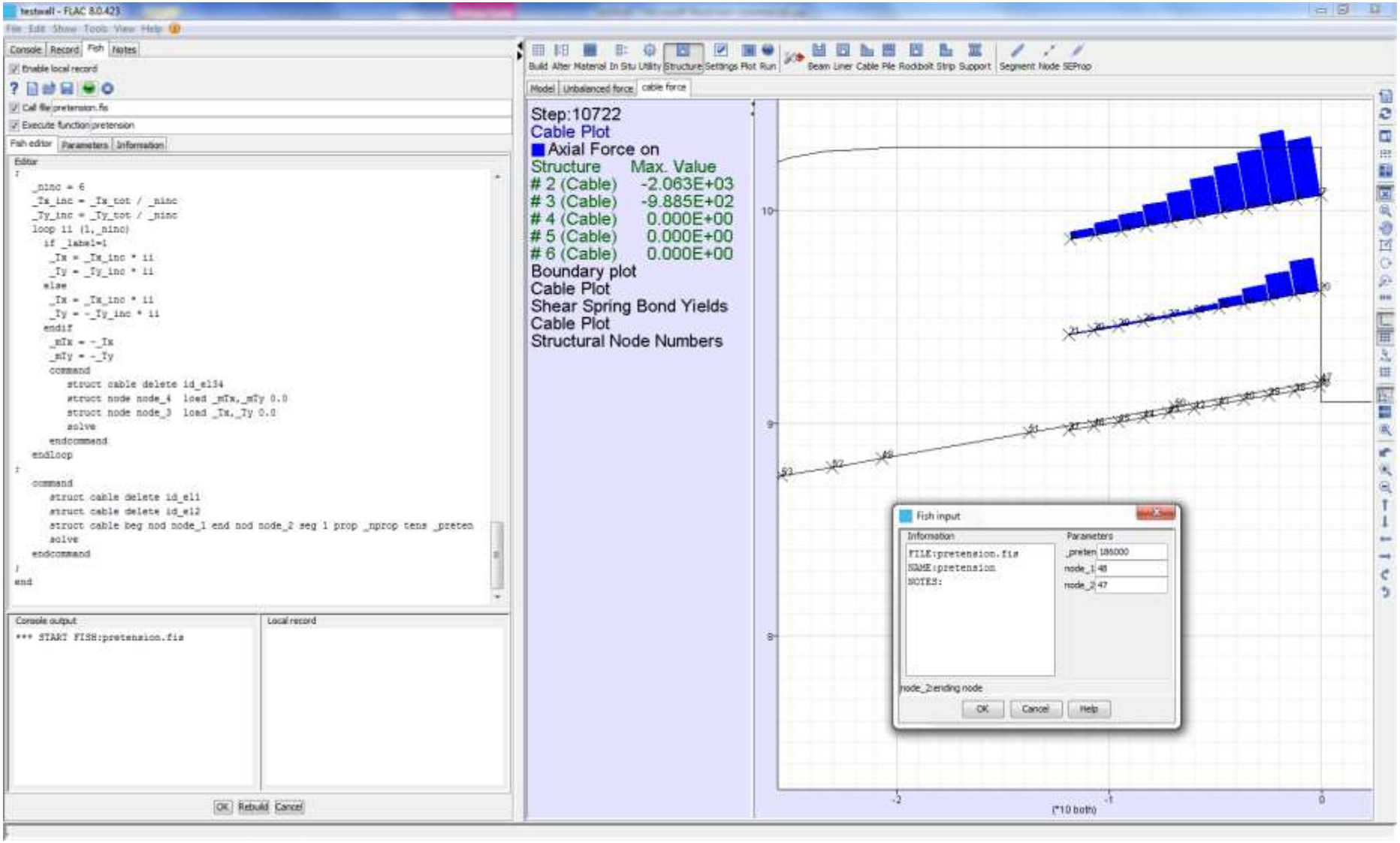


Step 5-9 In the [Structure]/[SEProp] tool, assign properties for the ungrouted portion of the tieback as shown. Note that tieback spacing is 9 ft. Press [OK] to send the commands to *FLAC*.

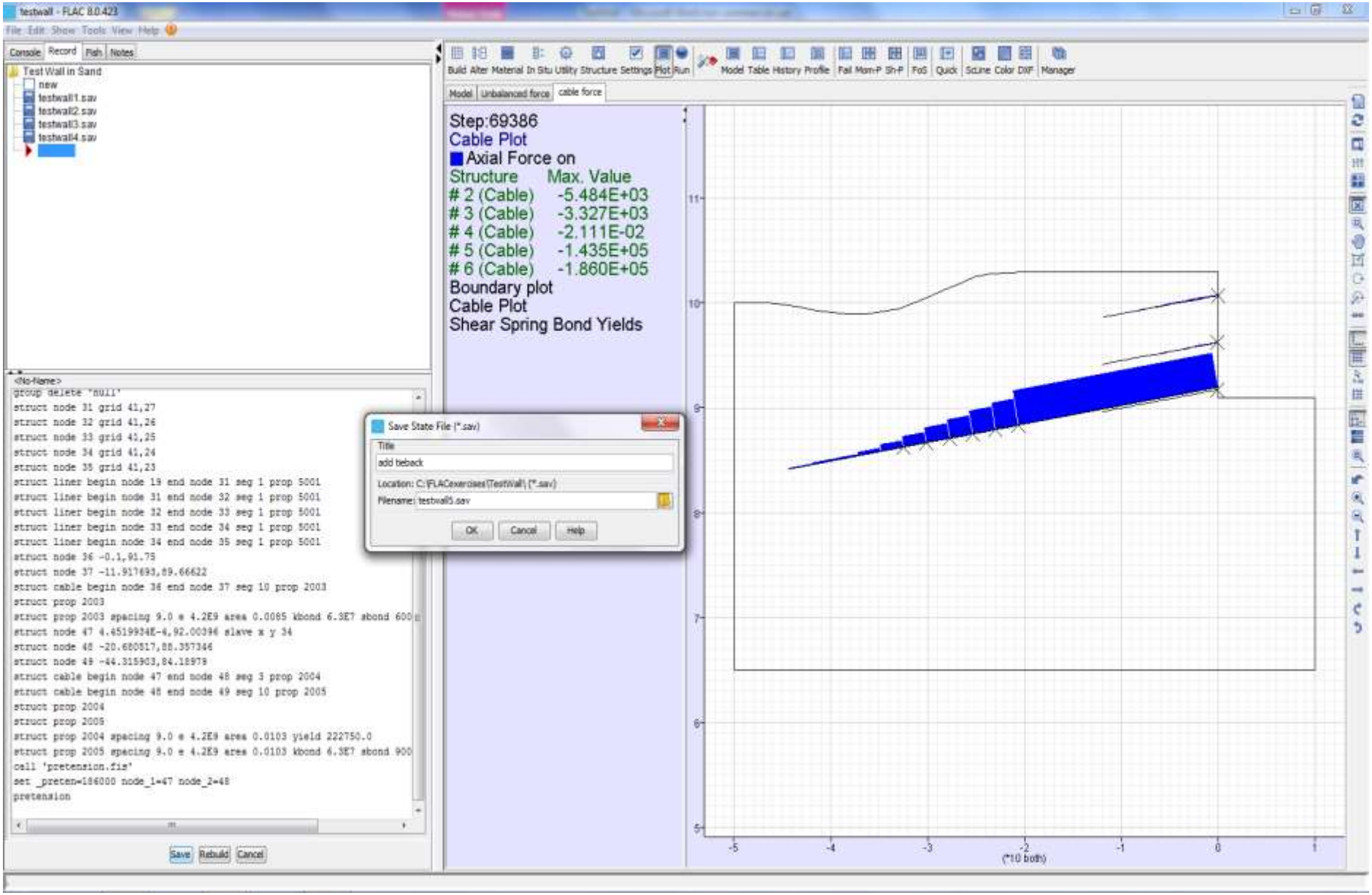




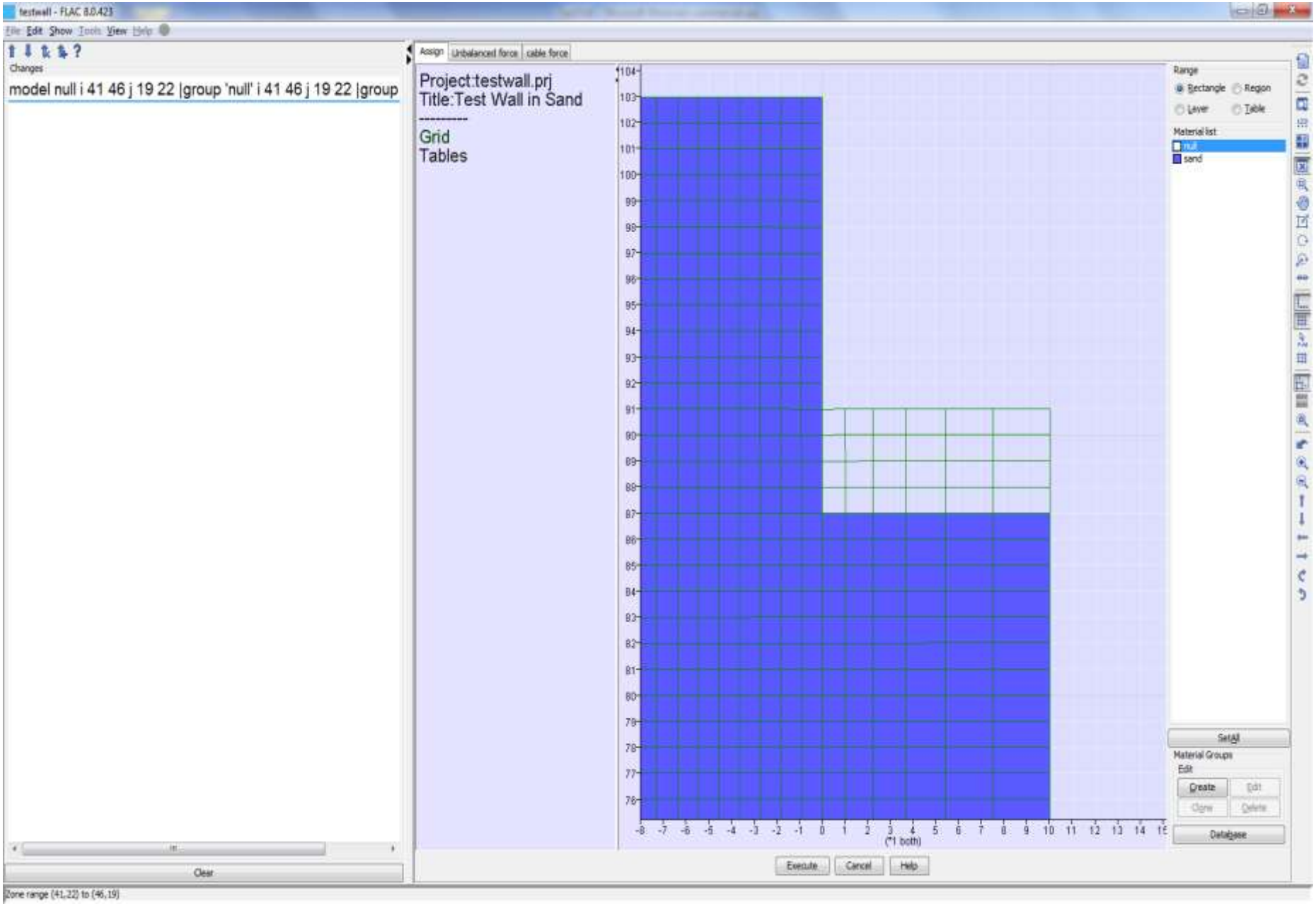
Step 5-10 In the [Structure]/[SEProp] tool, assign properties for the grouted portion of the tieback as shown. Note that tieback spacing is 9 ft. Press [OK] to send the commands to *FLAC*.



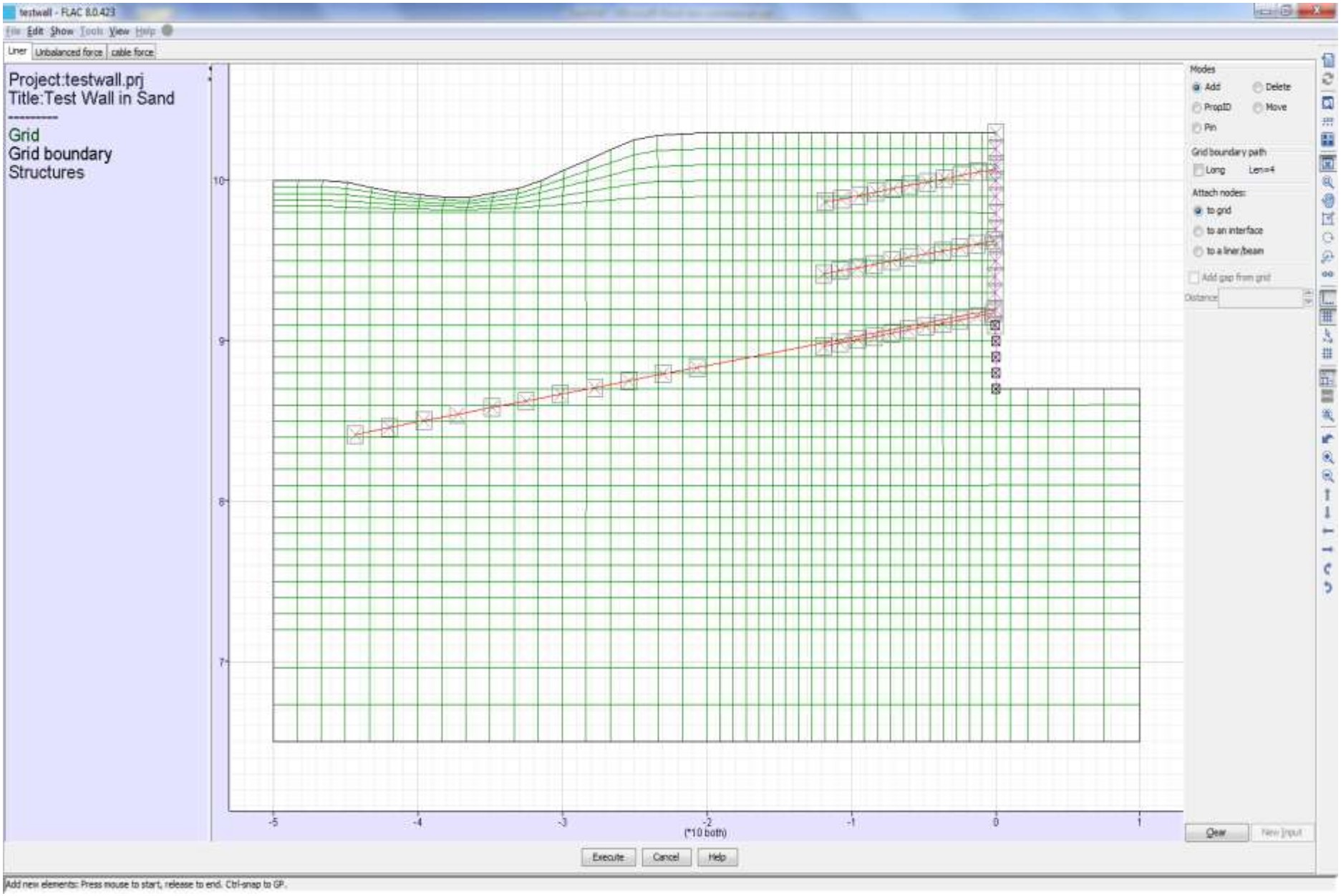
Step 5-11 Open pretension.fis in the [Fish editor] tool. Click on the execute button to open the *Fish input* dialog. The FISH function is described in Section 1.10.5 of the **Structural Elements** volume. The pretension value of 186,000 lb is assigned, and the starting and ending nodes of the ungrouted portion of the tieback (**node_1** = 48 and **node_2** = 47) are input. (Note that the starting node, **node_1**, must be the node with the lowest x-coordinate.) Press [OK] to execute the function.



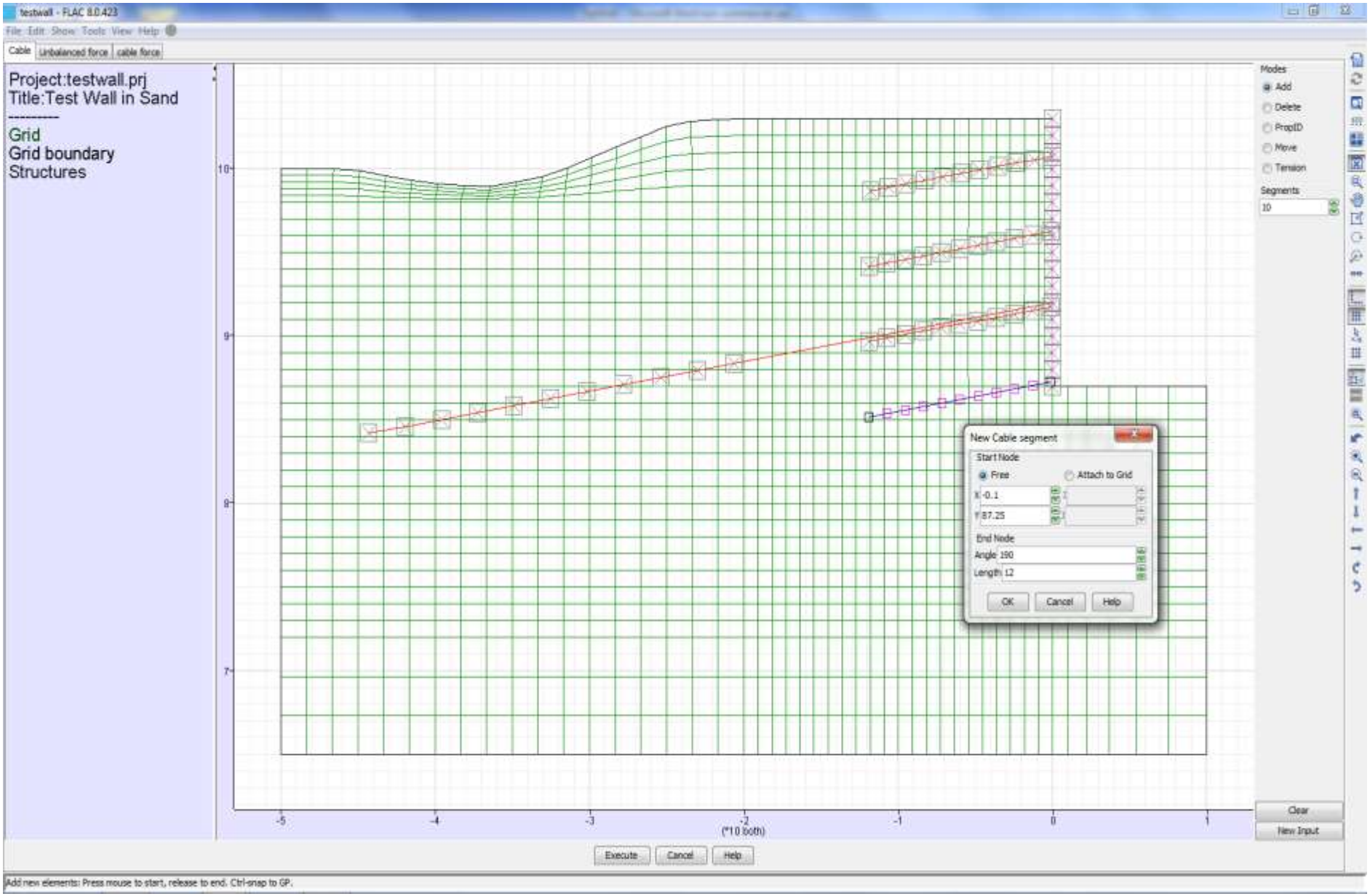
Step 5-12 When the calculation stops, return to the [Project] pane and check that the axial load in the cable is at the pretension value of 186,000 lb. Save the state as testwall5.sav.



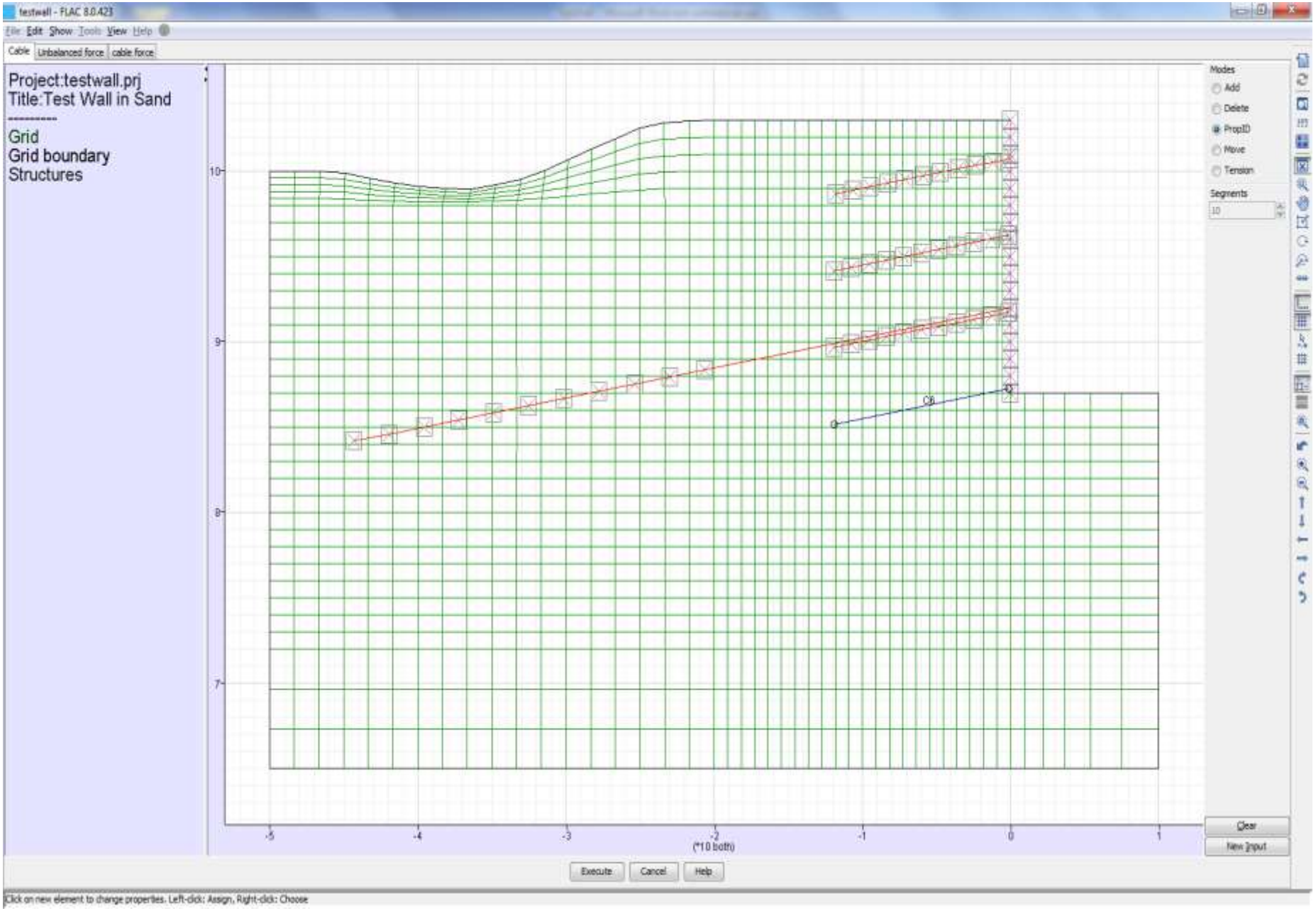
Step 6-1 Stage IV excavation – use the [Material]/[Assign] tool and select [null] material to excavate zones to the depth y=87.



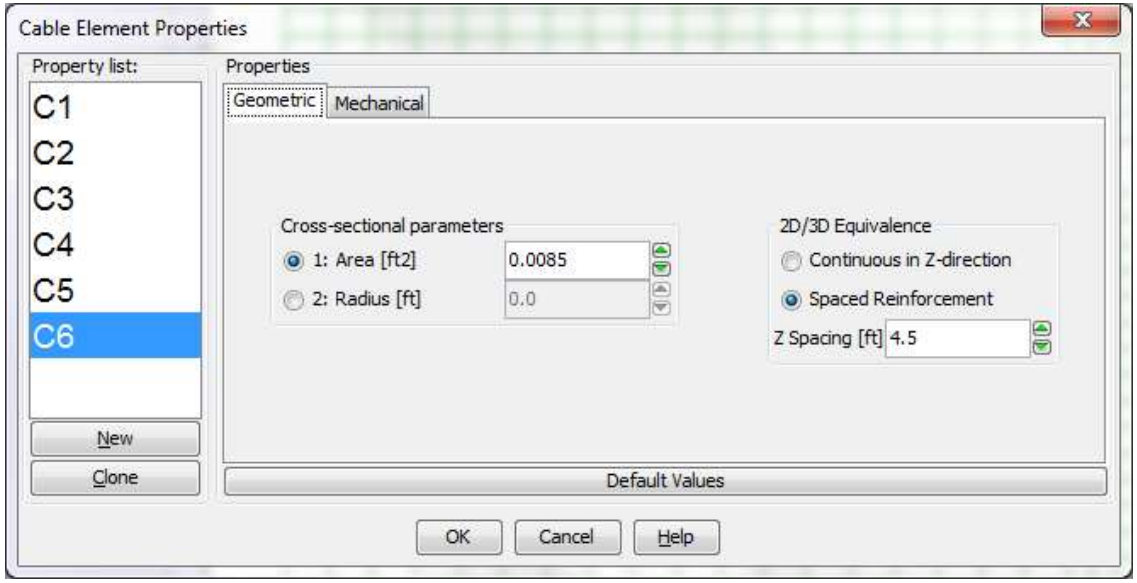
Step 6-2 In the [Structure]/[Liner] tool, check [Add] and drag the mouse along the boundary as shown to attach liner nodes to gridpoints in the excavation region. Press [Execute] to send the commands to *FLAC.*

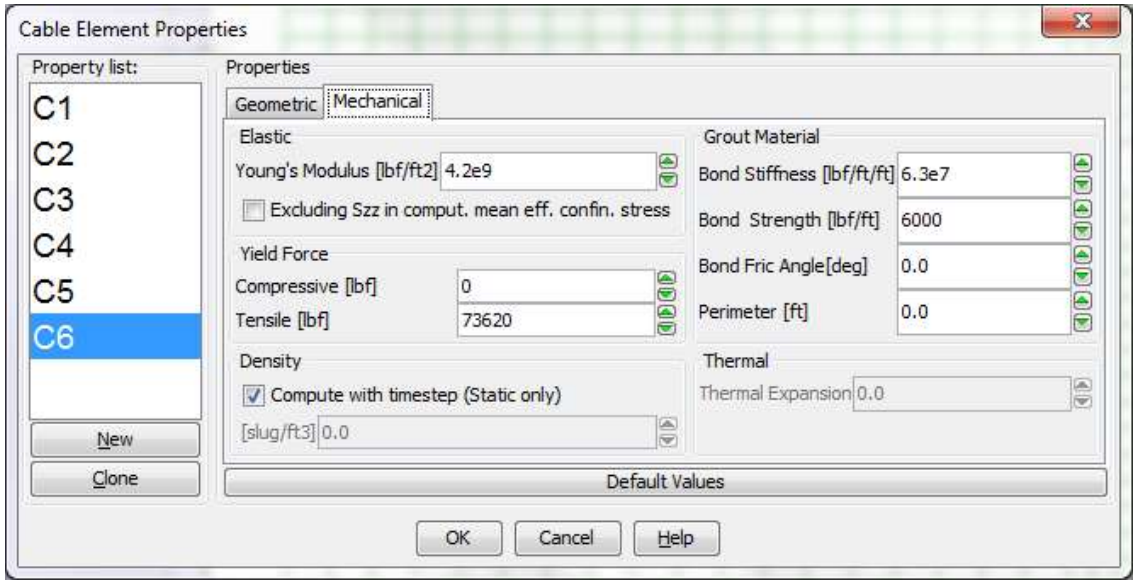


Step 6-3 In the [Structure]/[Cable] tool, check [Add], select 10 segments, and left click the mouse at a point inside the grid. This opens a *New Cable segment* dialog. Input a starting point at x=-0.1, y=87.25, and specify an angle of 190° and length of 12.0. The cable, composed of 10 segments, is created as shown.

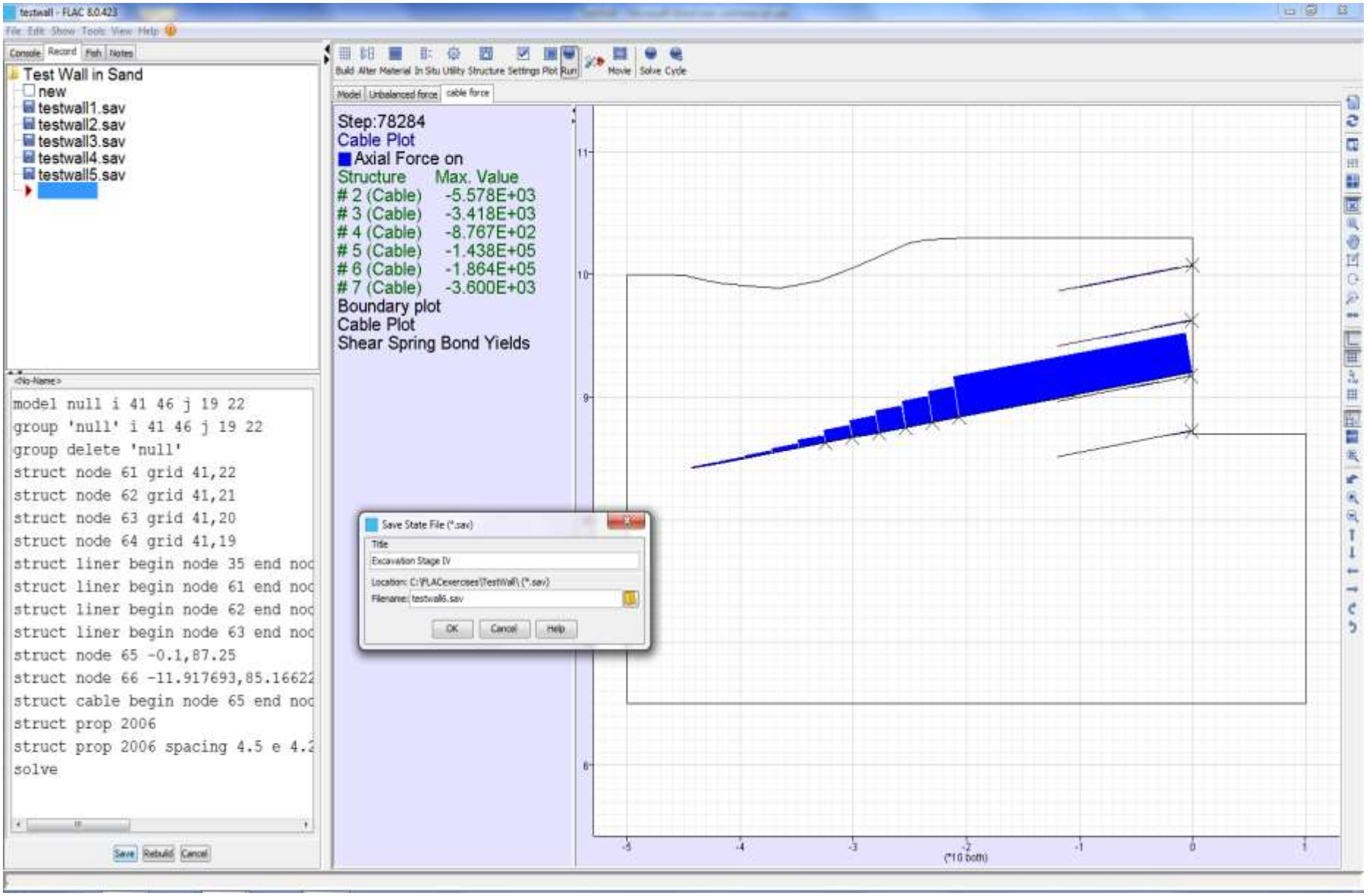


Step 6-4 Press [PropID] to change the property ID number for the new cable. Press [Execute] to send the commands to FLAC.

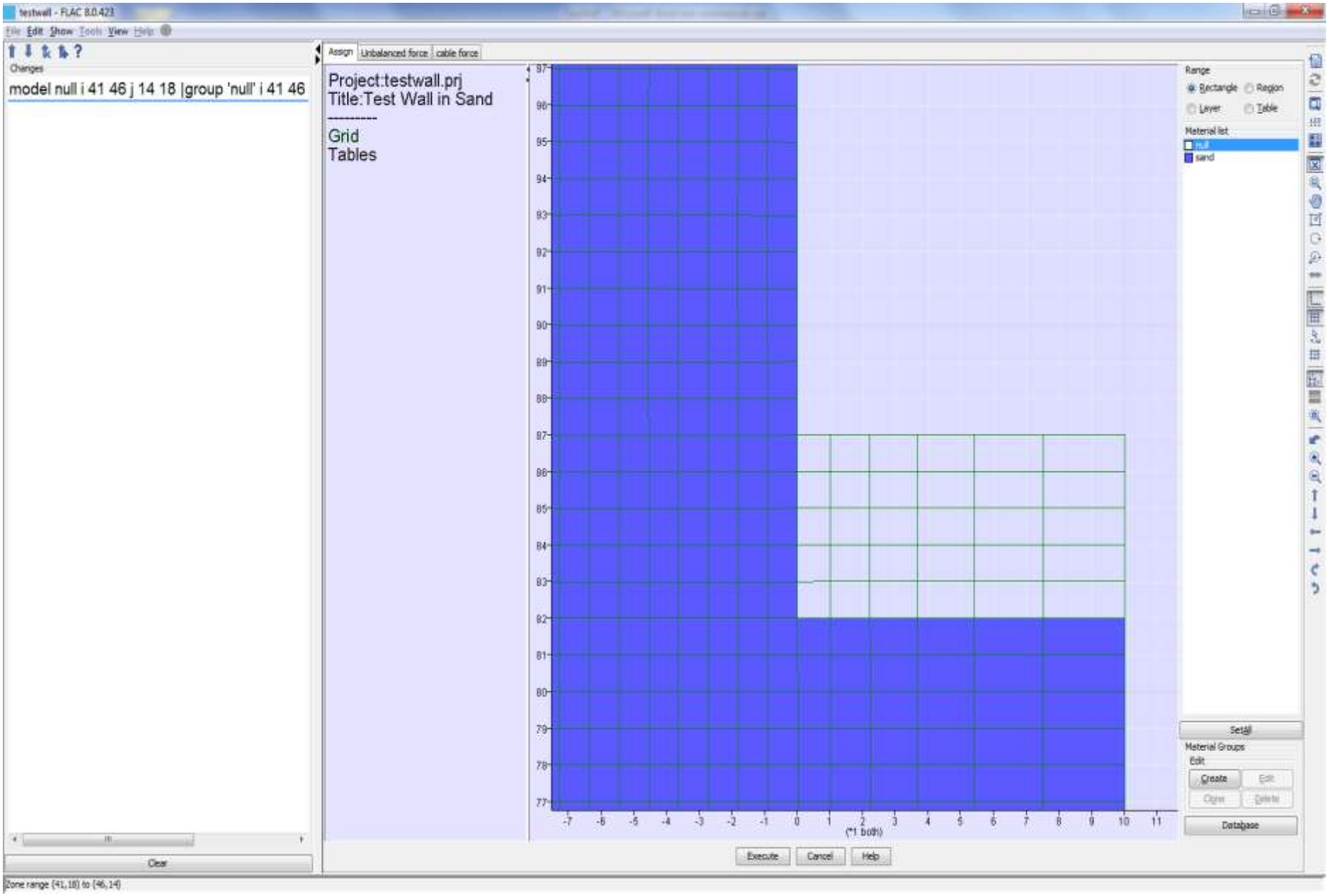




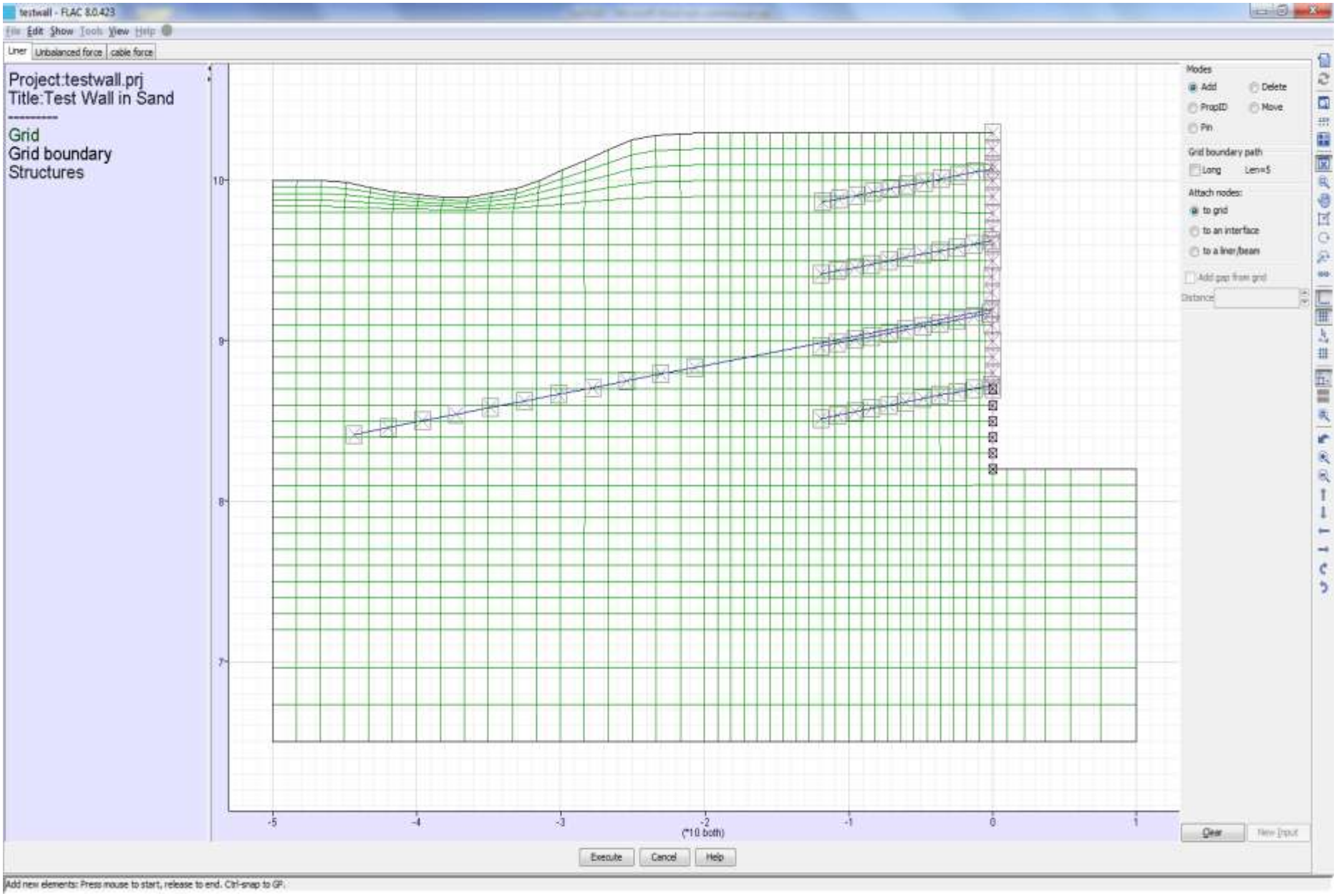
Step 6-5 In the [Structure]/[SEProp] tool, assign cable properties as shown. Note that cable spacing for the Row 4 cables is 4.5 ft. Press [OK] to send the commands to *FLAC*.



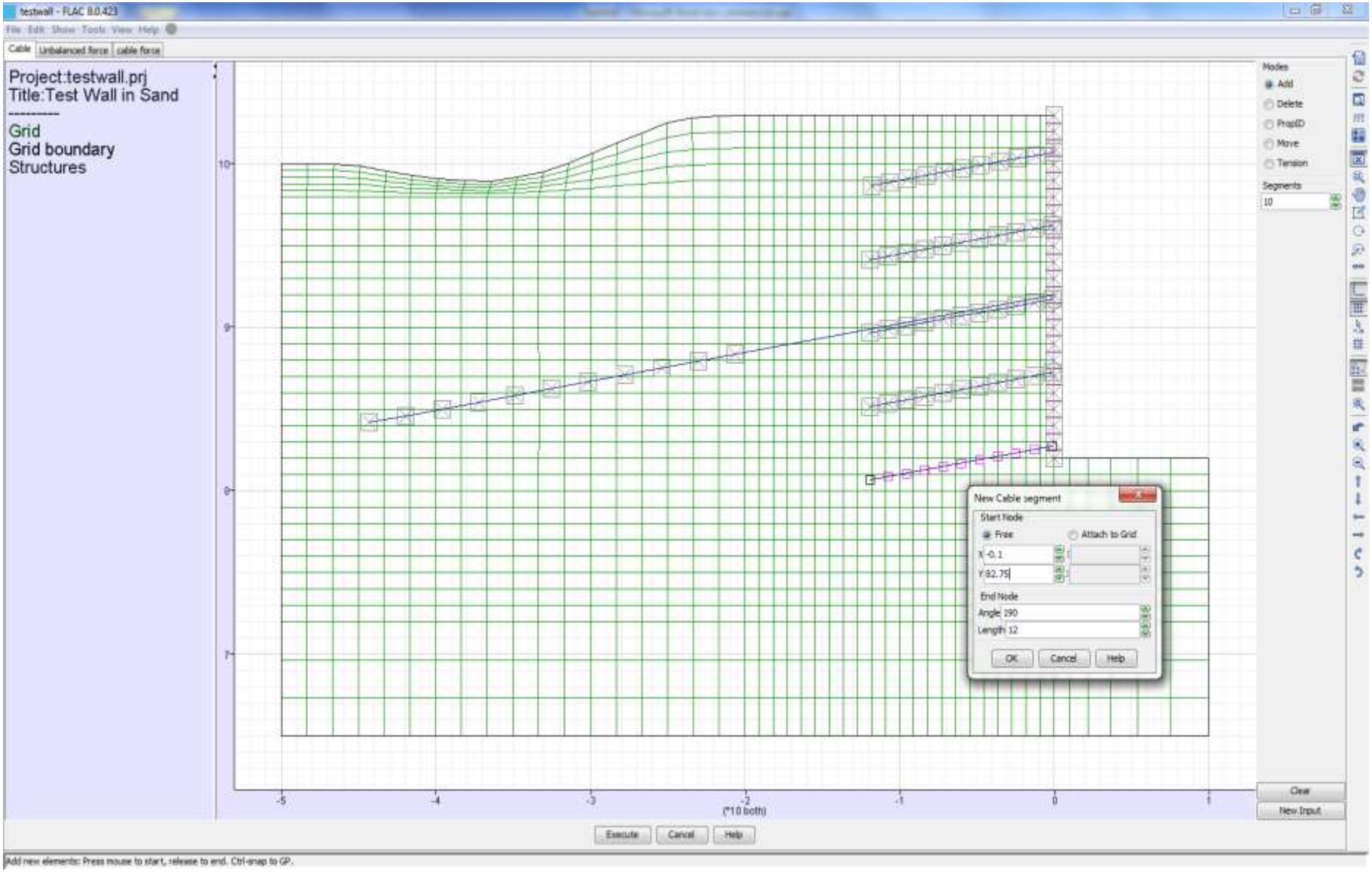
Step 6-6 Solve for the equilibrium state using the [Run]/[Solve] tool. Plot cable forces in the [Plot]/[Model] tool. Press [Save] to save the state as testwall6.sav.



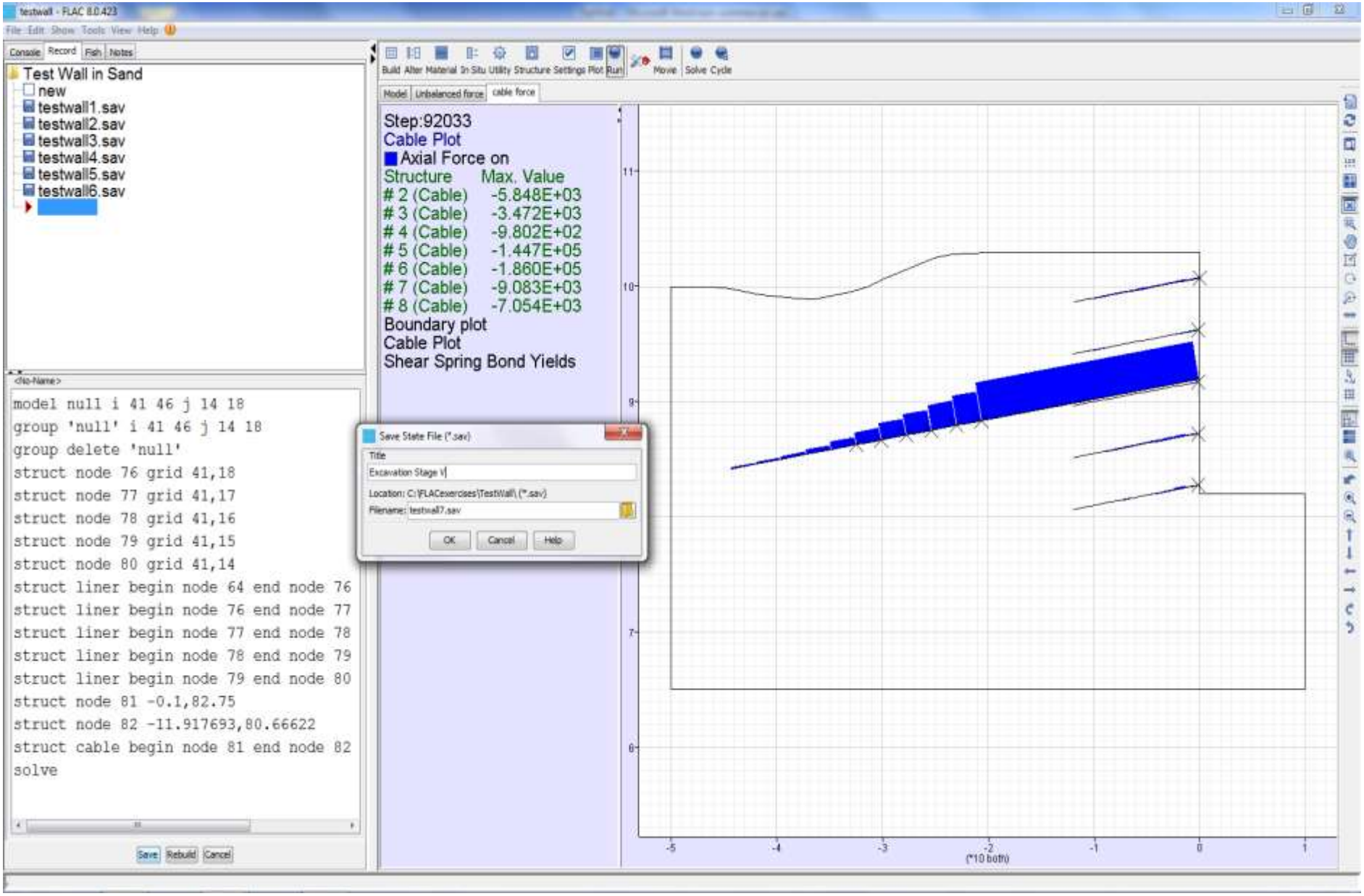
Step 7-1 Stage V excavation – use the [Material]/[Assign] tool and select [null] material to excavate zones to the depth y=82.



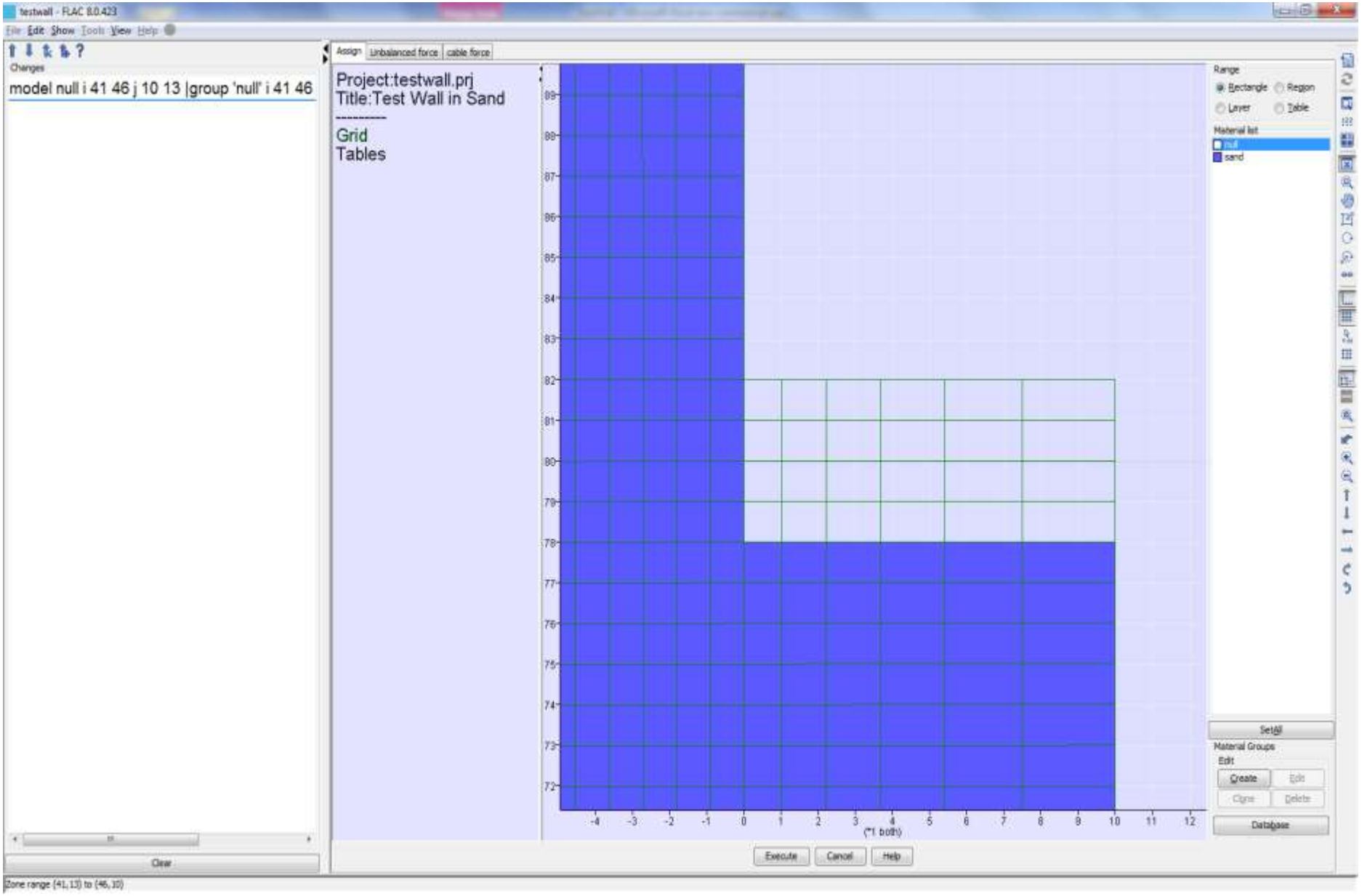
Step 7-2 In the [Structure]/[Liner] tool, check [Add] and drag the mouse along the boundary as shown to attach liner nodes to gridpoints in the excavation region. Press [Execute] to send the commands to *FLAC.*



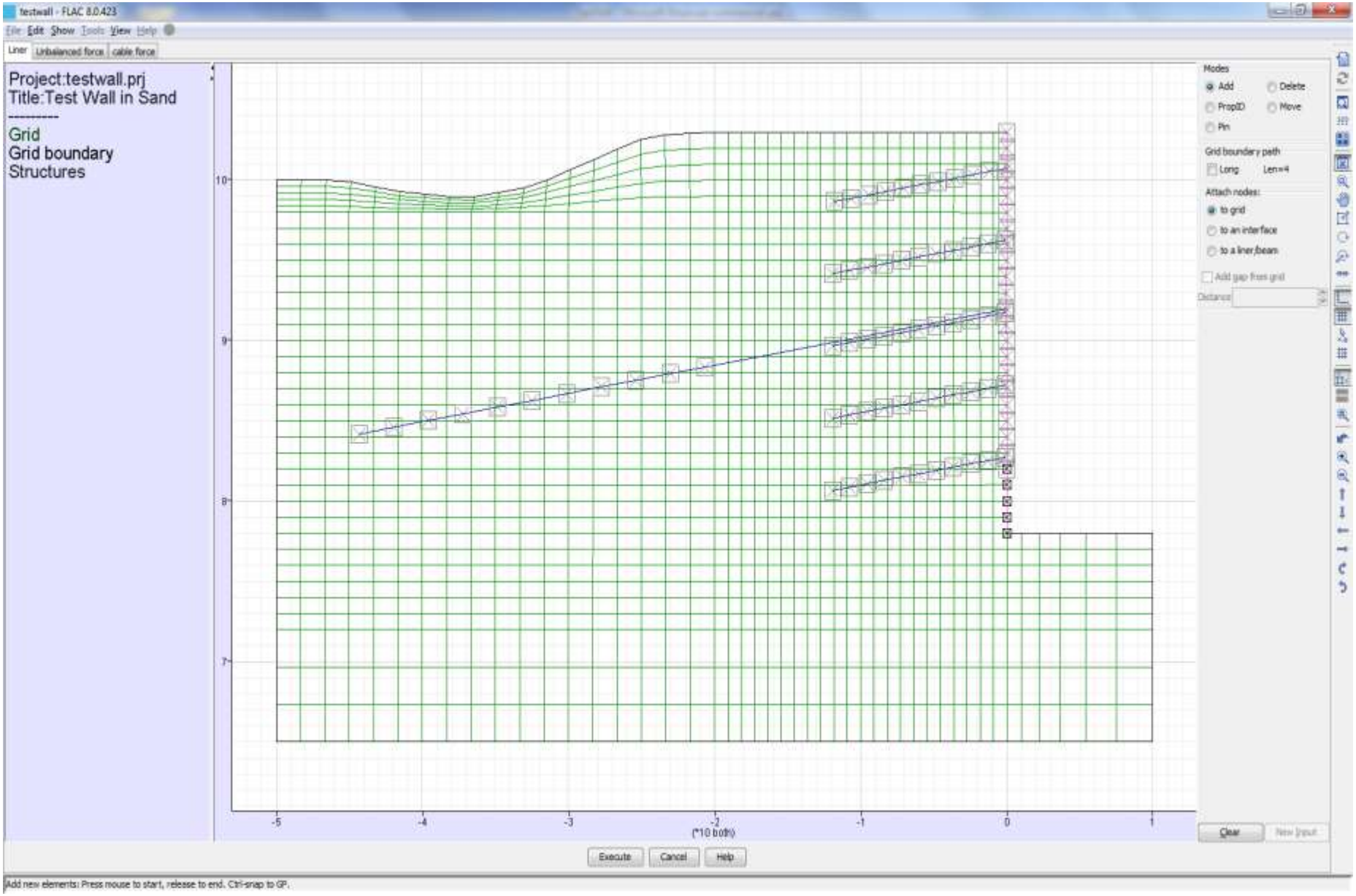
Step 7-3 In the [Structure]/[Cable] tool, check [Add], select 10 segments, and left click the mouse at a point inside the grid. This opens a *New Cable segment* dialog. Input a starting point at x=-0.1, y=82.25, and specify an angle of 190^{o} and length of 12.0. The cable, composed of 10 segments, is created as shown.



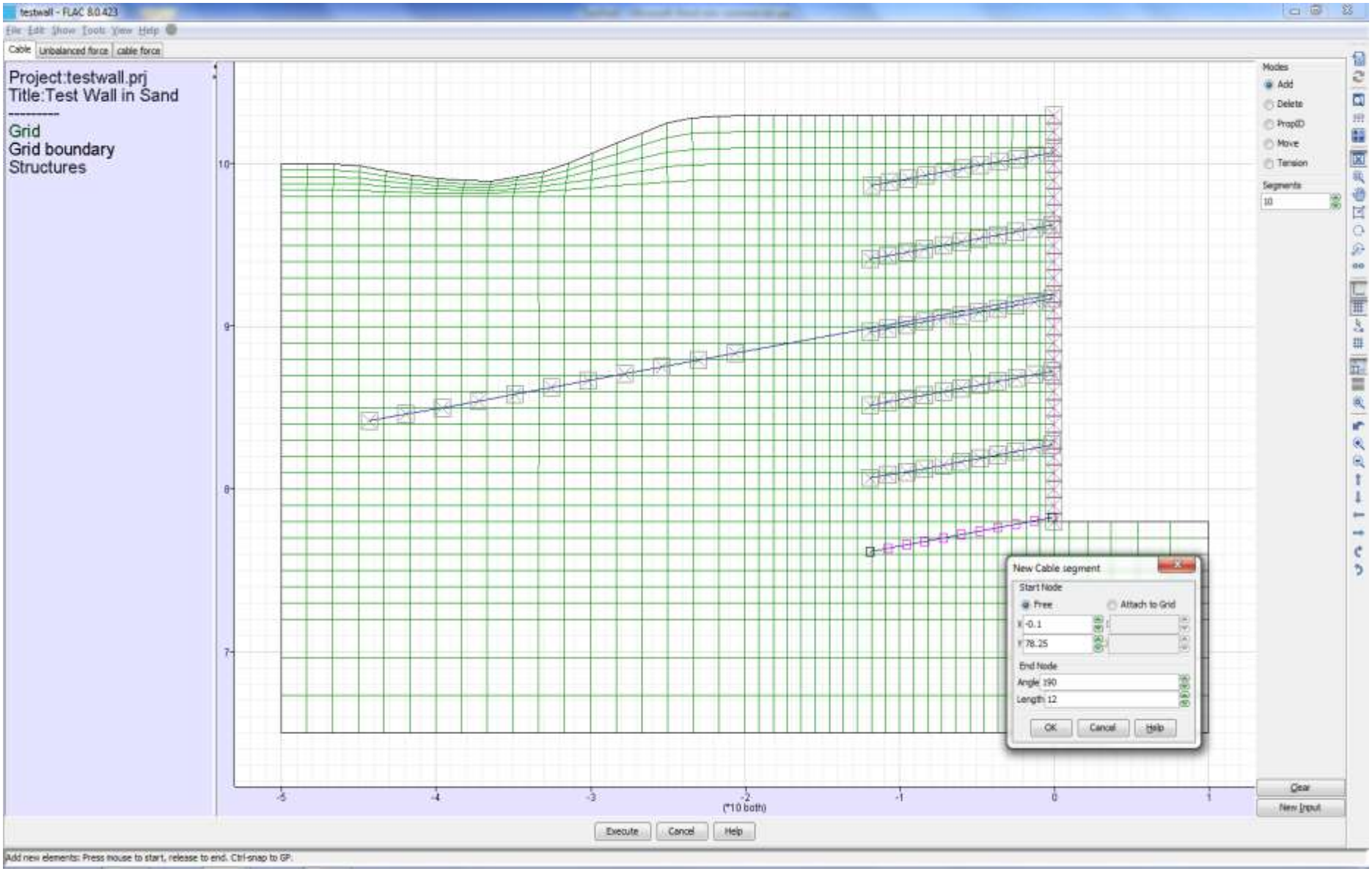
Step 7-4 Solve for the equilibrium state using the [Run]/[Solve] tool. Plot cable forces in the [Plot]/[Model] tool. Press [Save] to save the state as testwall7.sav.



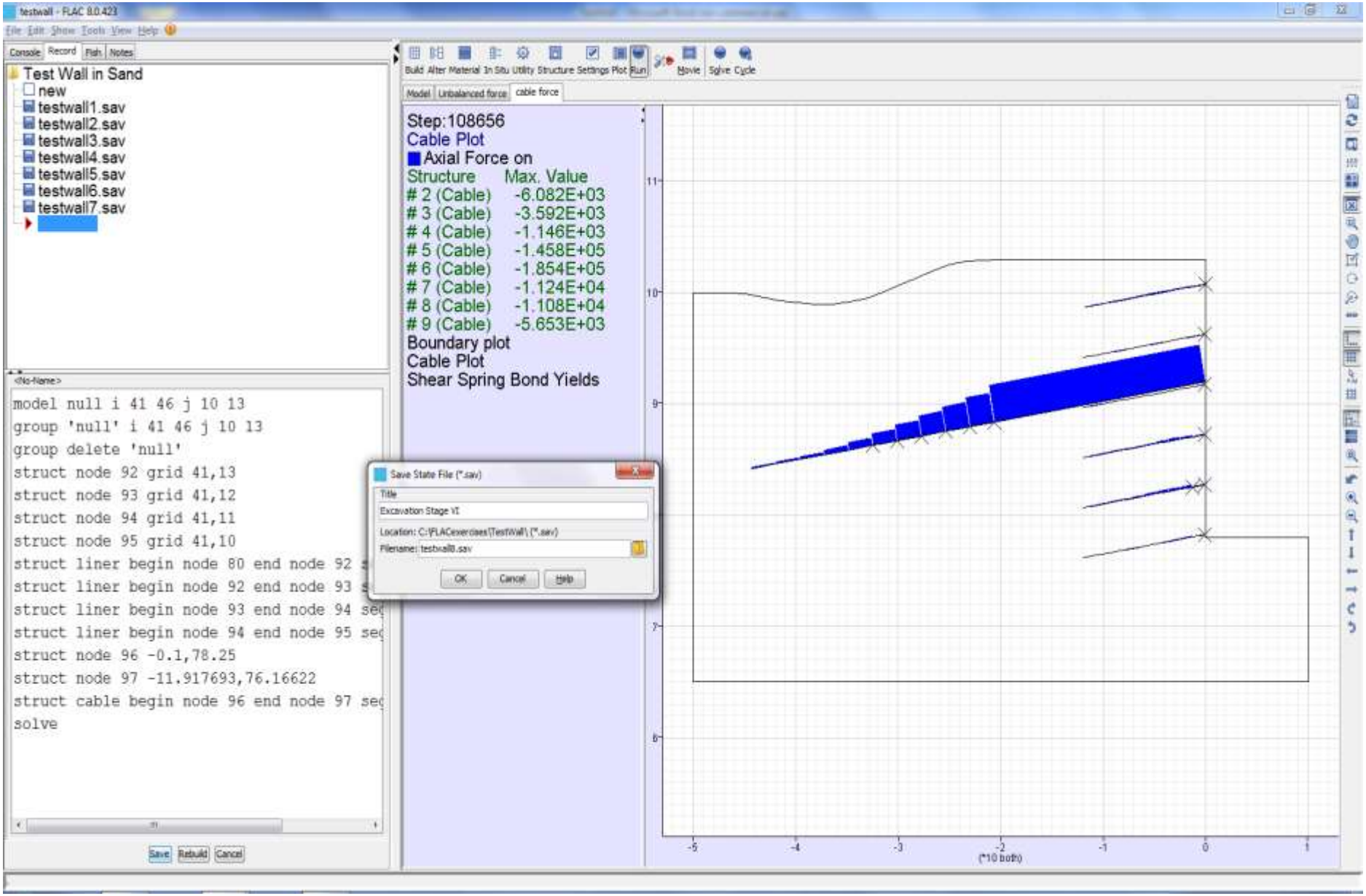
Step 8-1 Stage VI excavation – use the [Material]/[Assign] tool and select [null] material to excavate zones to the depth y=78.



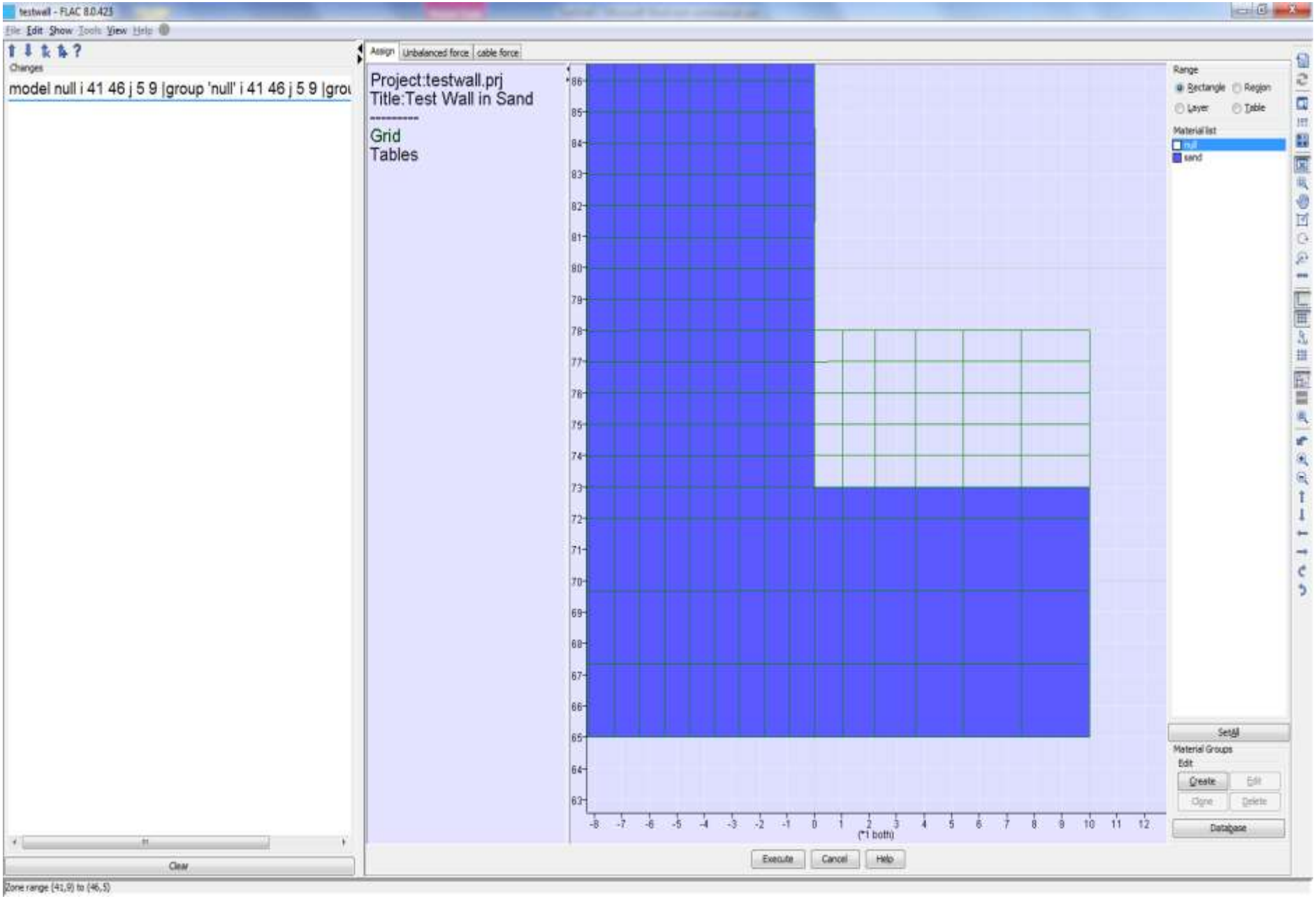
Step 8-2 In the [Structure]/[Liner] tool, check [Add] and drag the mouse along the boundary as shown to attach liner nodes to gridpoints in the excavation region. Press [Execute] to send the commands to *FLAC.*



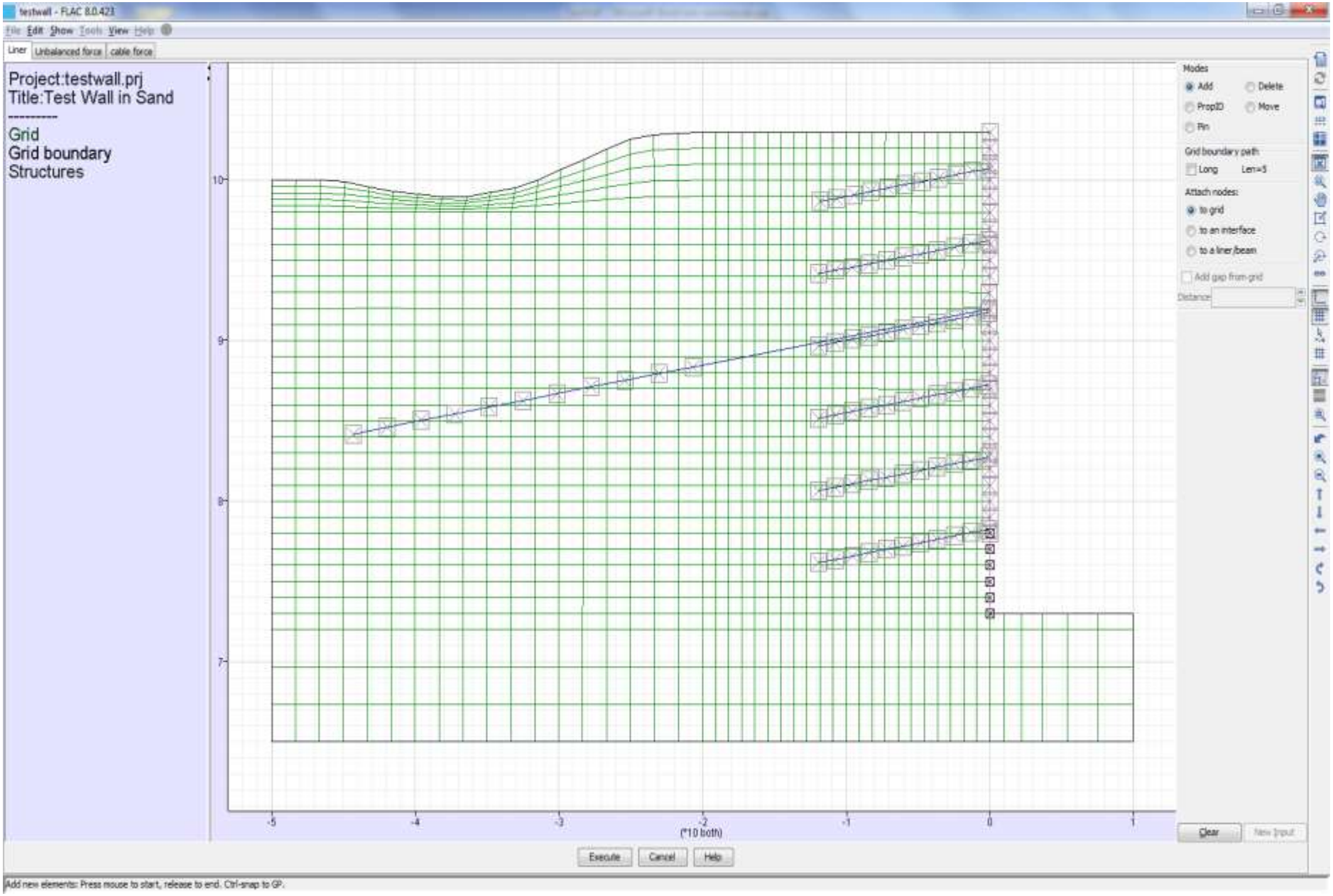
Step 8-3 In the [Structure]/[Cable] tool, check [Add], select 10 segments, and left click the mouse at a point inside the grid. This opens a *New Cable segment* dialog. Input a starting point at x=-0.1, y=78.25, and specify an angle of 190° and length of 12.0. The cable, composed of 10 segments, is created as shown.



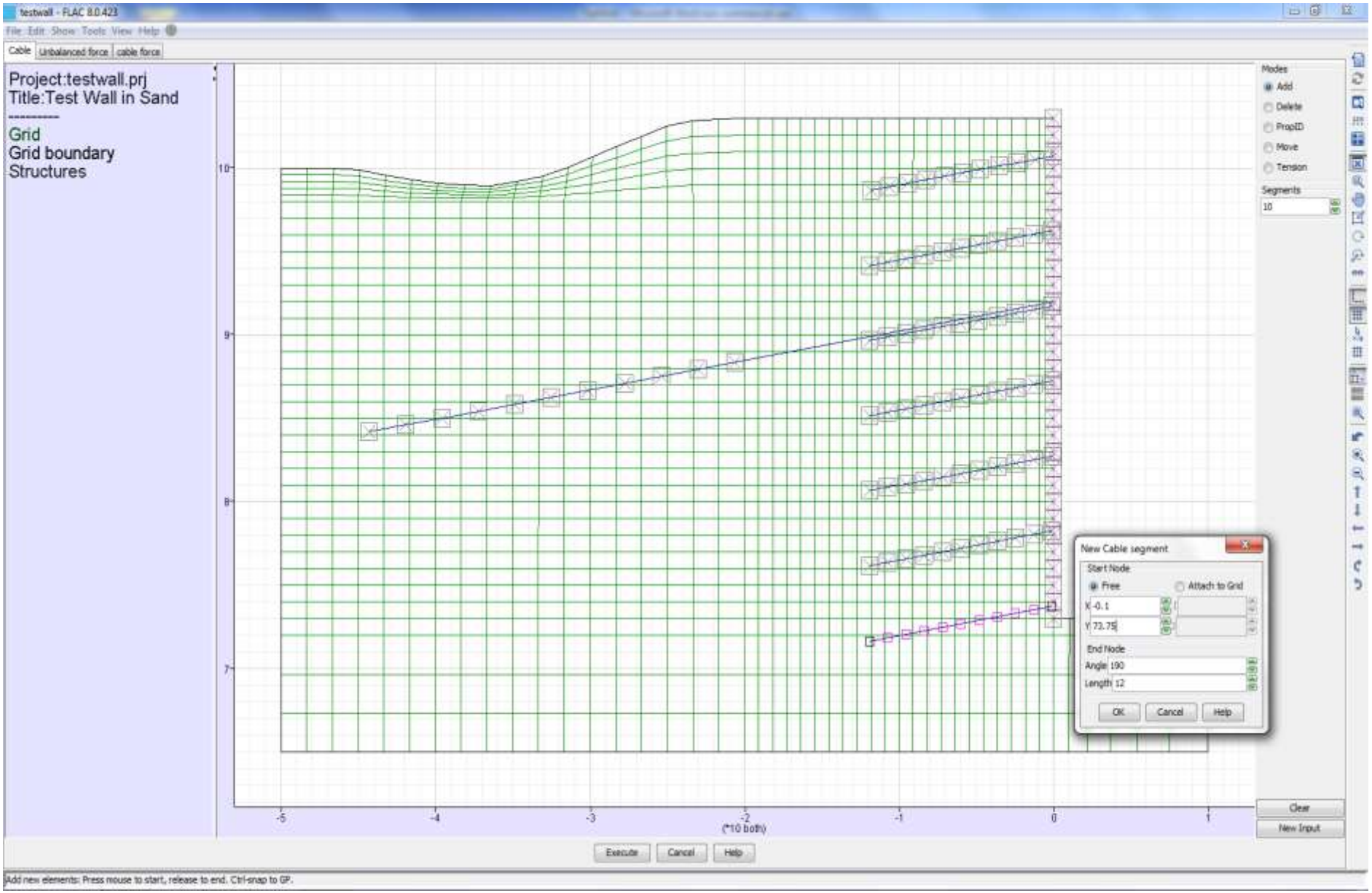
Step 8-4 Solve for the equilibrium state using the [Run]/[Solve] tool. Plot cable forces in the [Plot]/[Model] tool. Press [Save] to save the state as testwall8.sav.



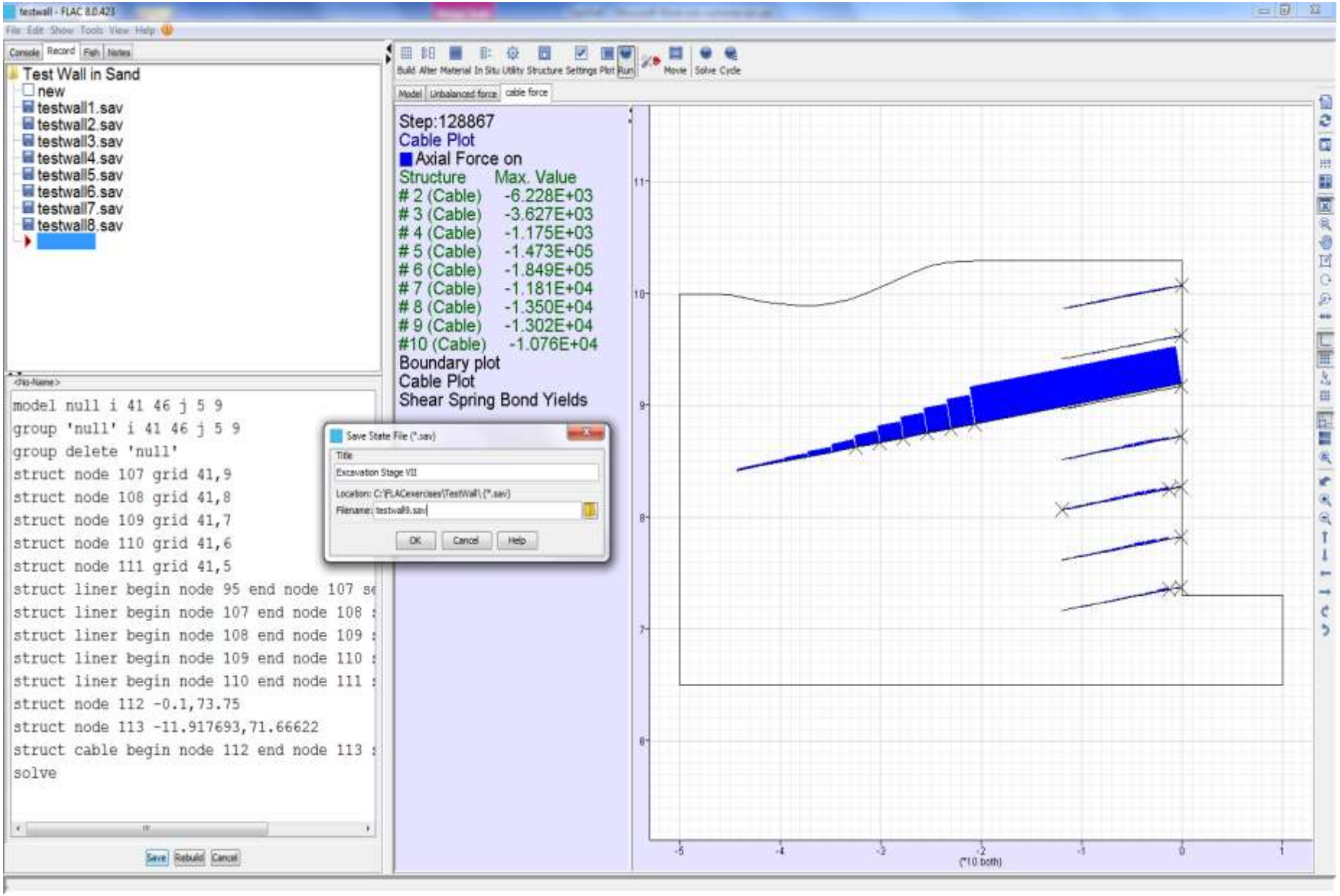
Step 9-1 Stage VII excavation – use the [Material]/[Assign] tool and select [null] material to excavate zones to the depth y=73.



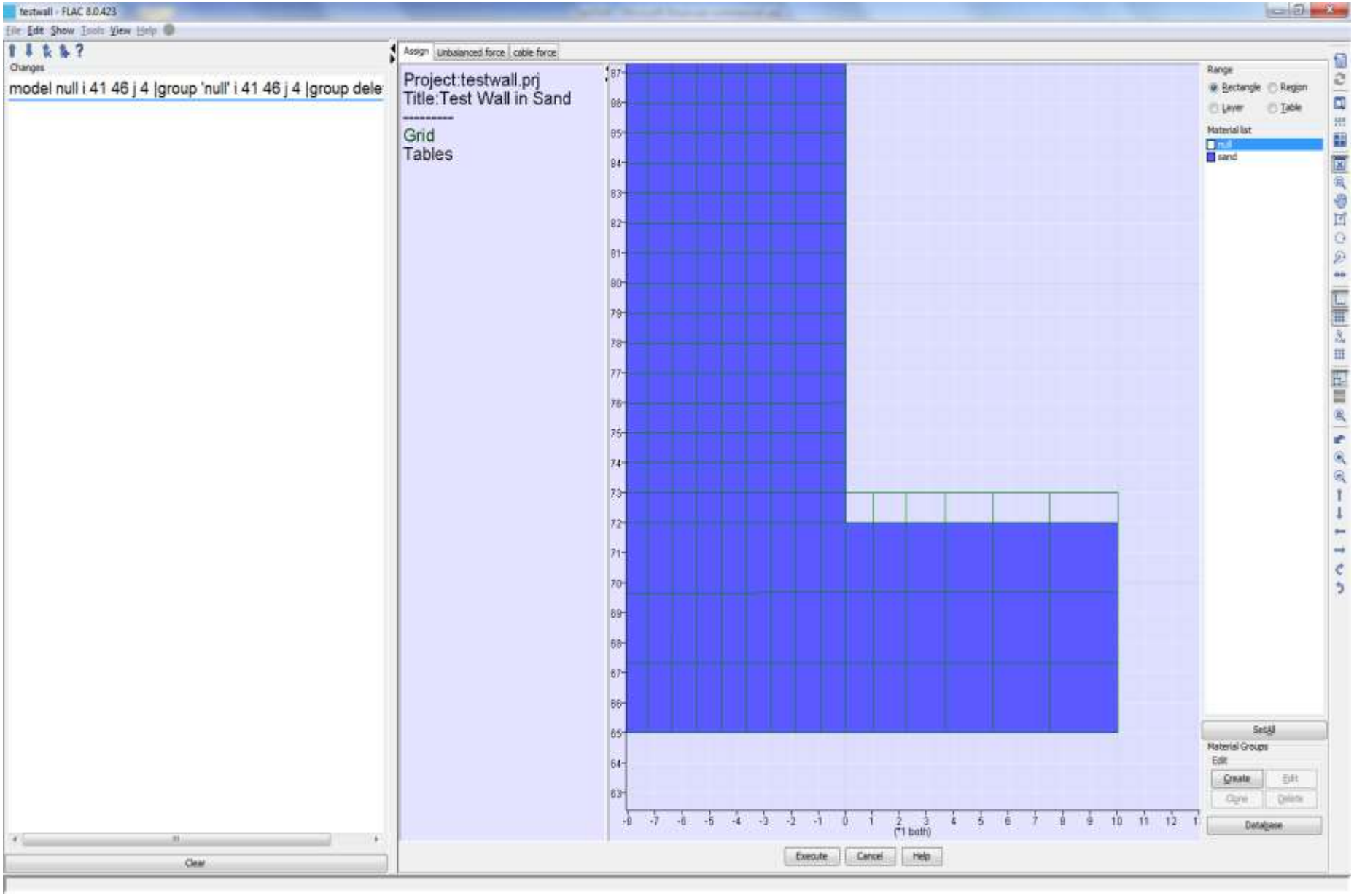
Step 9-2 In the [Structure]/[Liner] tool, check [Add] and drag the mouse along the boundary as shown to attach liner nodes to gridpoints in the excavation region. Press [Execute] to send the commands to *FLAC.*



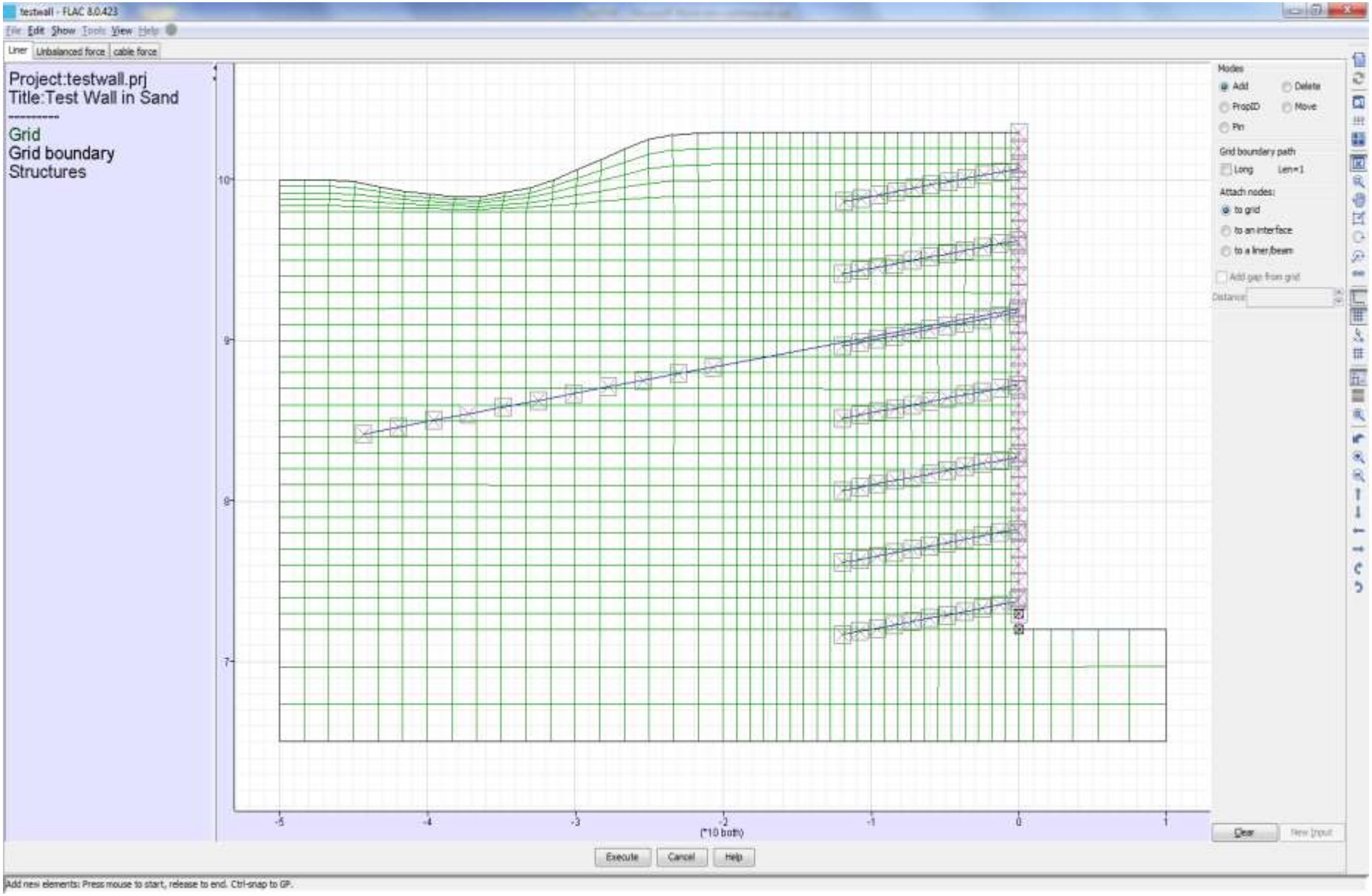
Step 9-3 In the [Structure]/[Cable] tool, check [Add], select 10 segments, and left click the mouse at a point inside the grid. This opens a *New Cable segment* dialog. Input a starting point at x=-0.1, y=73.75, and specify an angle of 190^{o} and length of 12.0. The cable, composed of 10 segments, is created as shown.



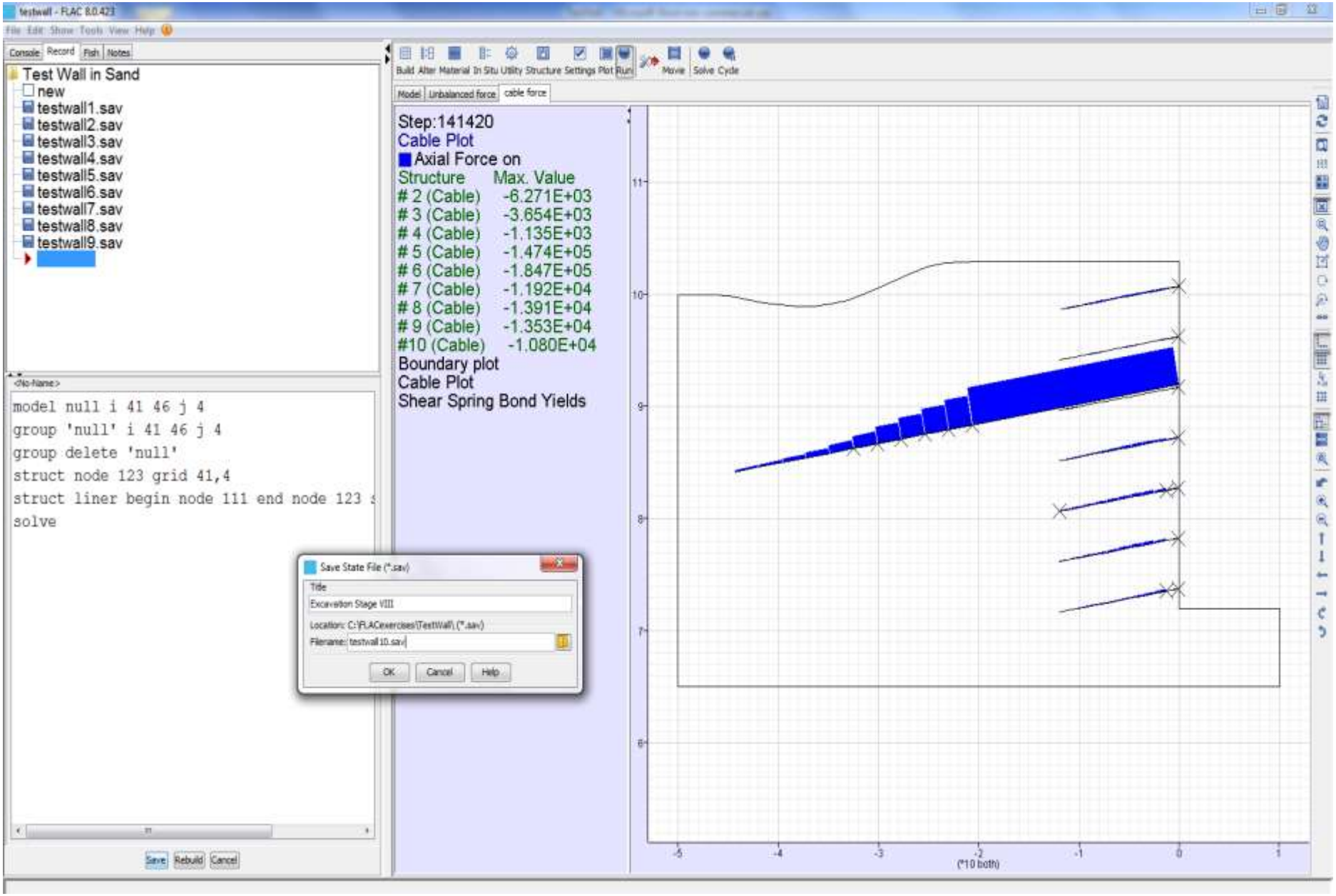
Step 9-4 Solve for the equilibrium state using the [Run]/[Solve] tool. Plot cable forces in the [Plot]/[Model] tool. Press [Save] to save the state as testwall9.sav.



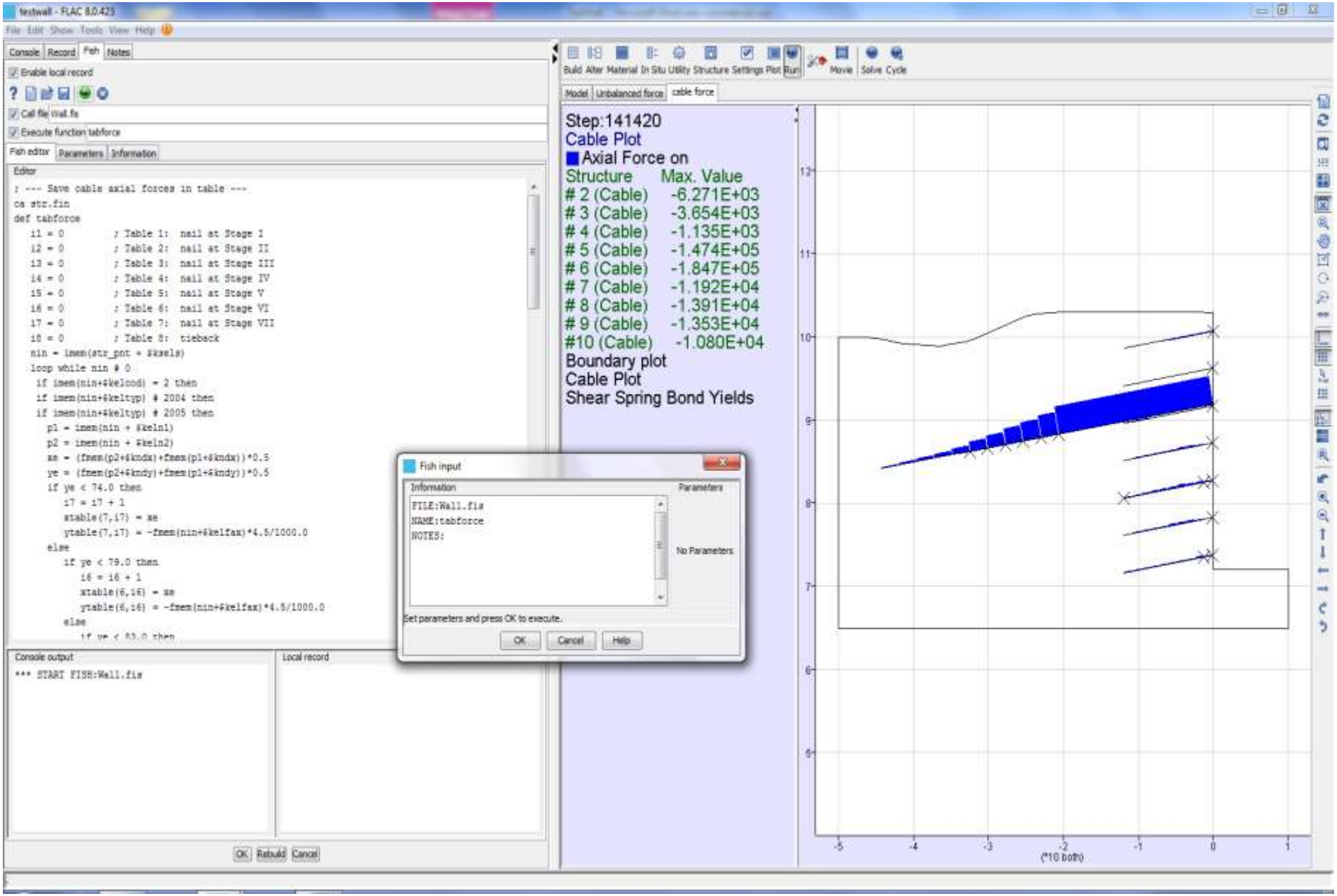
Step 10-1 Stage VIII excavation – use the [Material]/[Assign] tool and select [null] material to excavate zones to the depth y=72.



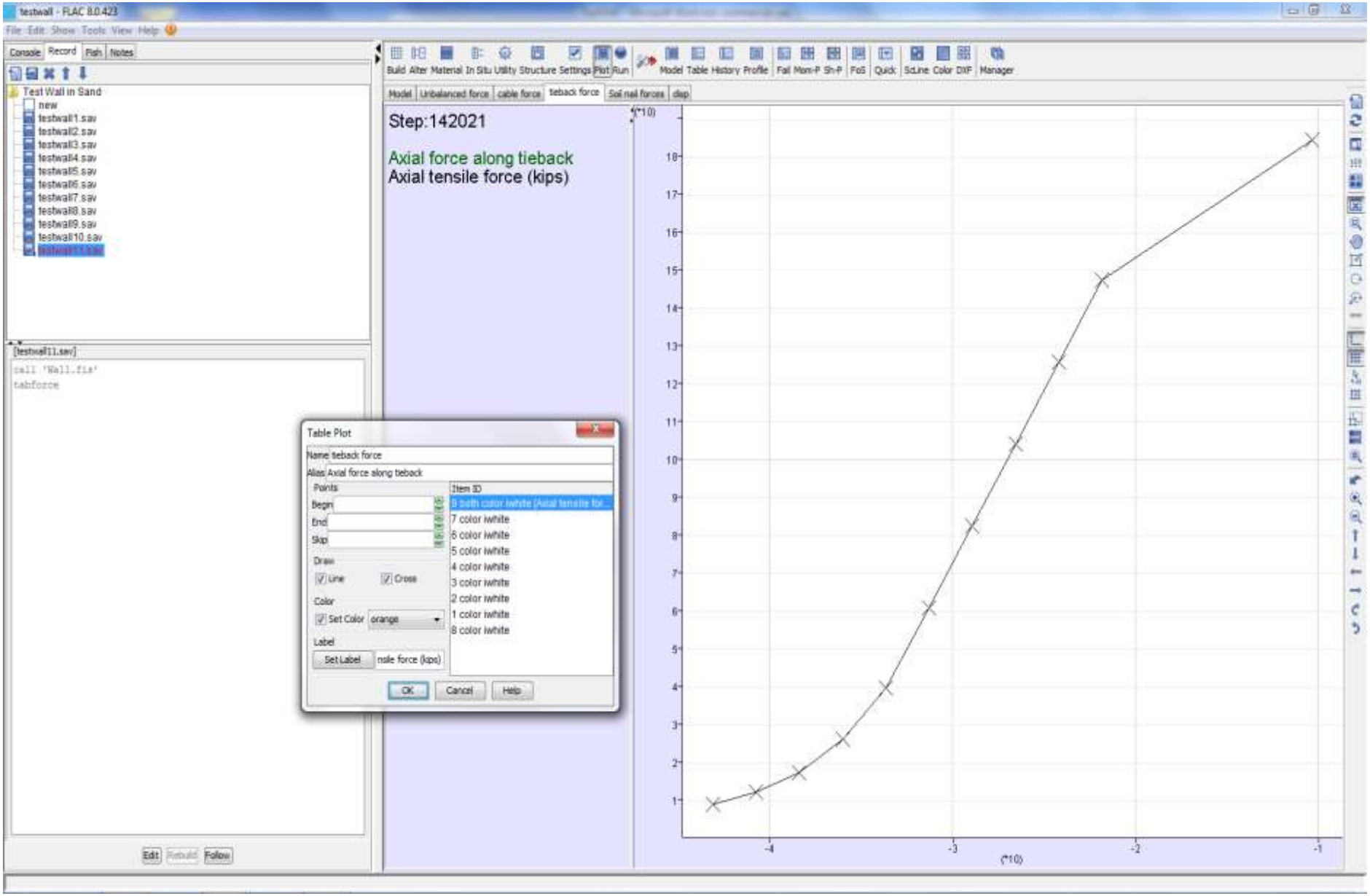
Step 10-2 In the [Structure]/[Liner] tool, check [Add] and drag the mouse along the boundary as shown to attach liner nodes to gridpoints in the excavation region. Press [Execute] to send the commands to *FLAC.*



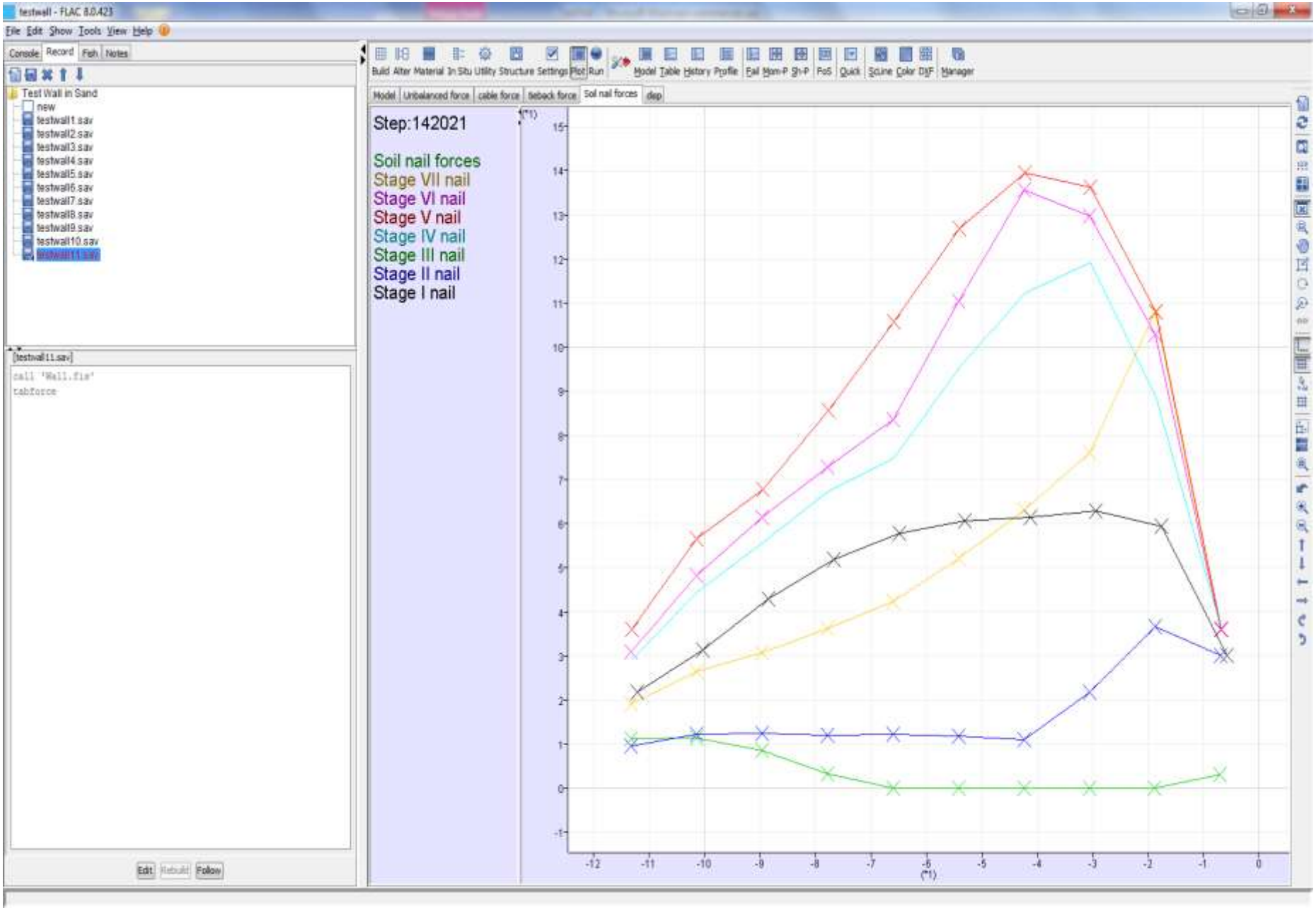
Step 10-3 Solve for the equilibrium state using the [Run]/[Solve] tool. Plot cable forces in the [Plot]/[Model] tool. Press [Save] to save the state as testwall9.sav.



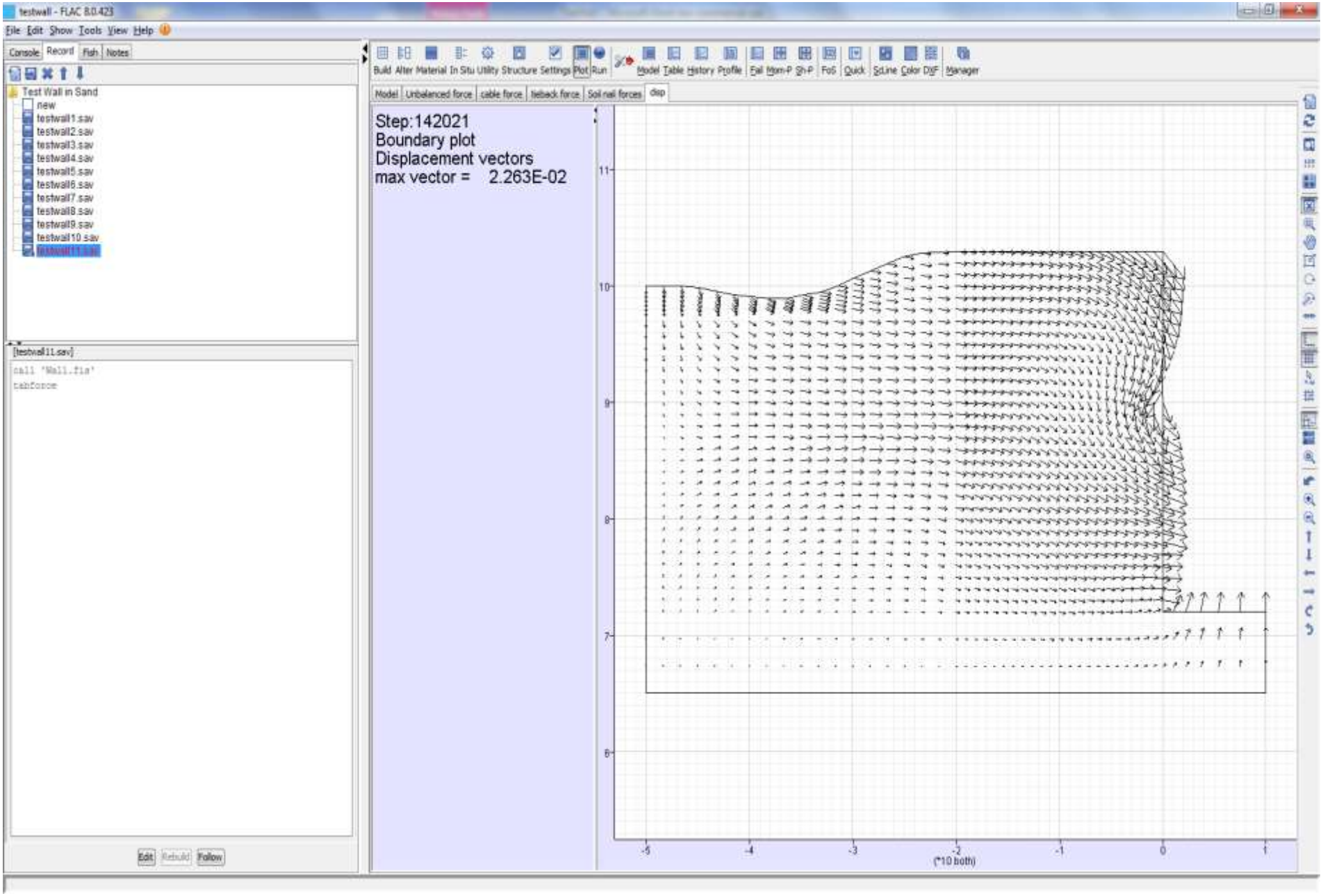
Step 11-1 FISH function, wall.fis, plots actual values in the tieback and soil nails. Enter the [Fish Editor] and open and execute wall.fis.



Step 11-2 Use the [Plot]/[Table] tool to plot tieback forces. Table 9 contains the axial force along the tieback. (Note that forces are first stored in table 8 and then reordered along the length of the tieback and stored in table 9.)



Step 11-3 Use the [Plot]/[Table] tool to plot soil nail forces. Tables 1 through 7 contain the axial forces along the soil nails.



Step 11-4 Use the [Plot]/[Model] tool to plot displacement vectors.