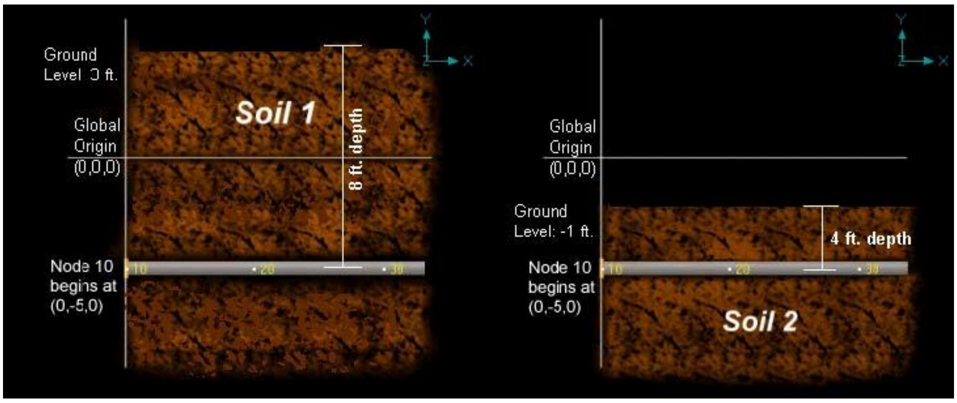
Tutorial for Soil Modeling for Buried Piping using CAEPIPE

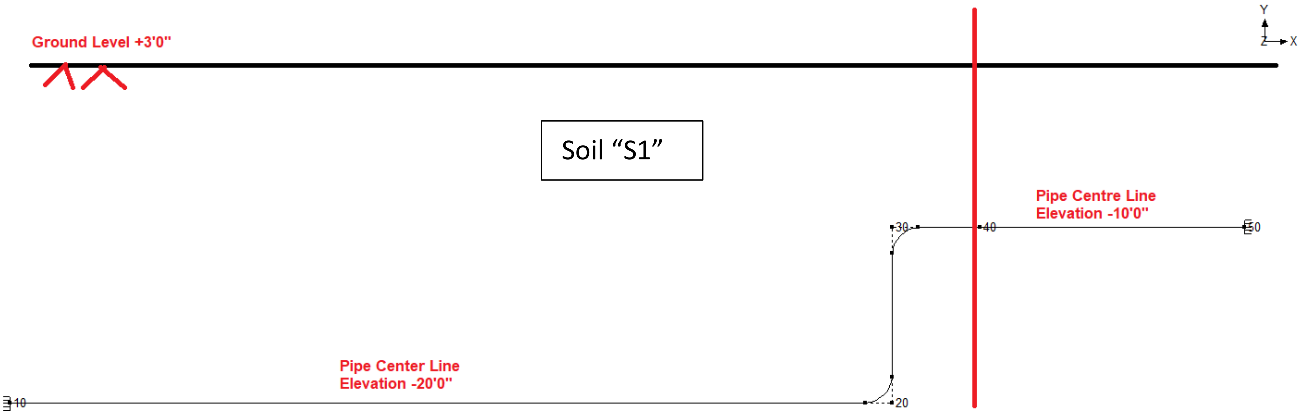
Ground level for soil in CAEPIPE is the height of the soil surface from the global origin (height could be positive or negative). It is NOT a measure of the depth of the pipe's centerline.

In the figure below, the height of the soil surface is 3 feet above the global origin. Pipe node 10 [model origin] is defined at (0,-5,0). So, the pipe is buried 8' (3' - [-5']) deep into the soil. The pipe centerline is calculated by CAEPIPE from the given data

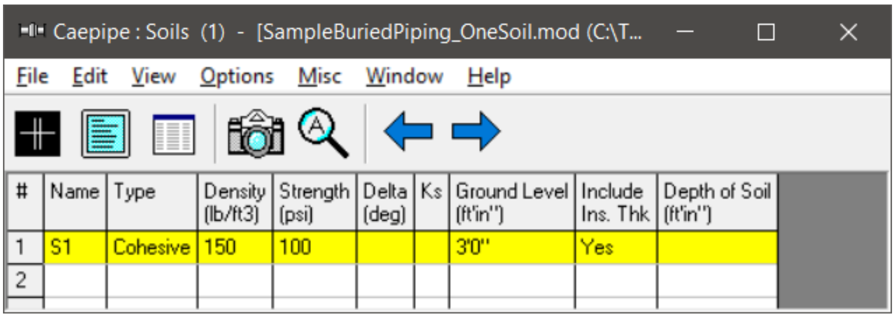


This tutorial shows different cases of Soil modelling for Buried Piping Analysis.

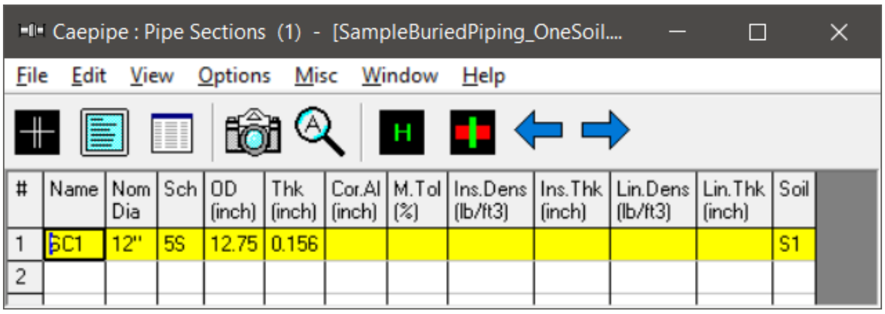
Case 1: Piping layout buried under same type of soil



In the Figure shown above, 12" Schedule STD piping is assumed to be buried in same type of soil throughout. To represent the case shown above, you need to define in CAEPIPE, a section card "SC1" and a soil "S1" with its properties and Ground Level as +3'0". After defining the property of soil, tie soil "S1" defined with the section "SC1" for the stress layout defined using Nodes 10 through 50. When done, CAEPIPE will automatically compute the depth of soil above Nodes 10 and 20 as 23'0" [= +3'0" - (-20'0")]. Similarly, for Nodes 30, 40 and 50, the depth of soil will be internally computed as 13'0" [= +3'0" - (-10'0")]. See the model SampleBuriedPiping_OneSoil.mod for details.



#	Name	Type	Density (lb/ft3)	Strength (psi)	Delta (deg)	Ks	Ground Level (ft'in")	Include Ins. Thk	Depth of Soil (ft'in")
1	S1	Cohesive	150	100			3'0"	Yes	
2									



Caepipe : Pipe Sections (1) - [SampleBuriedPiping_OneSoil...

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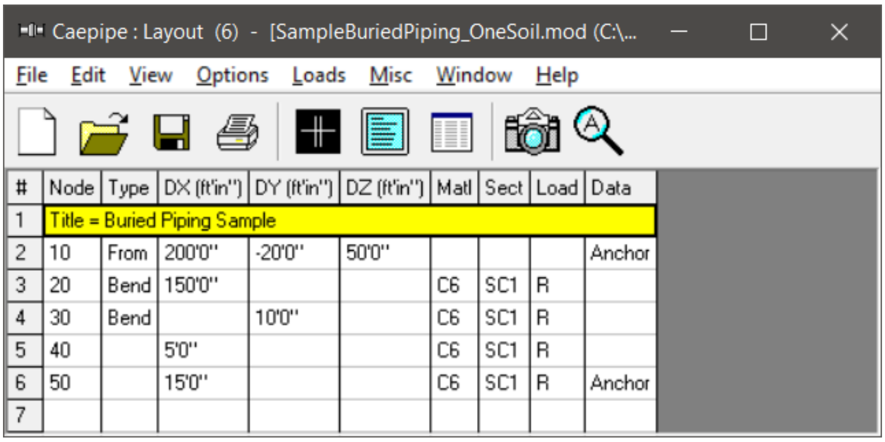
#	Name	Nom Dia	Sch	OD (inch)	Thk (inch)	Cor.Al (inch)	M.Tol (%)	Ins.Dens (lb/ft3)	Ins.Thk (inch)	Lin.Dens (lb/ft3)	Lin.Thk (inch)	Soil
1	SC1	12"	5S	12.75	0.156							S1
2												



Caepipe : Layout (6) - [SampleBuriedPiping_OneSoil.mod (C:\...

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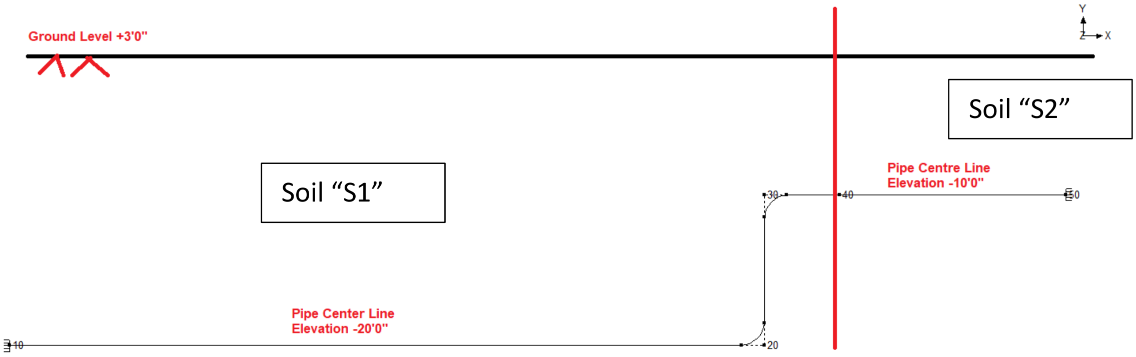
#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Buried Piping Sample								
2	10	From	200'0"	-20'0"	50'0"				Anchor
3	20	Bend	150'0"			C6	SC1	R	
4	30	Bend		10'0"		C6	SC1	R	
5	40		5'0"			C6	SC1	R	
6	50		15'0"			C6	SC1	R	Anchor
7									

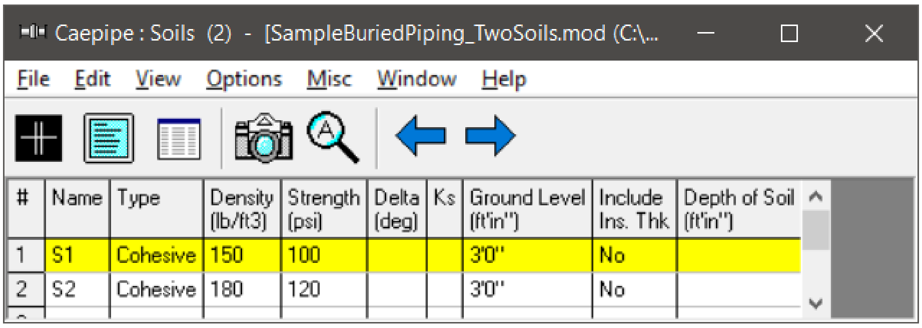
Case 2: Piping Layout buried under different type of soils



In the Figure shown above, 12" Schedule STD piping is assumed to be buried under two type of soils "S1" and "S2" with Ground level as +3'0".

To represent this case, you need to define two section cards say "SC1" and "SC2" with their Nominal size as 12" and Schedule as "STD". Following this, define two soils "S1" and "S2" with their required properties and Ground level as +3'0". After defining the soils, tie the soil "S1" with "SC1" and "S2" with "SC2". Then in the layout define the Section as "SC1" for Elements from Node 10 through Node 40 and define the Section as "SC2" for Element between Node 40 and 50. When done, CAEPIPE will automatically compute the depth of soil above Nodes 10 through 50 as explained in Case 1.

See the model SampleBuriedPiping_TwoSoils.mod for details.



Caepipe : Soils (2) - [SampleBuriedPiping_TwoSoils.mod (C:\...

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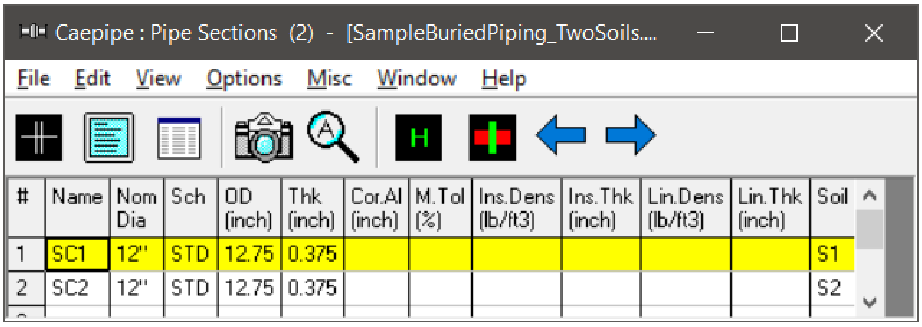
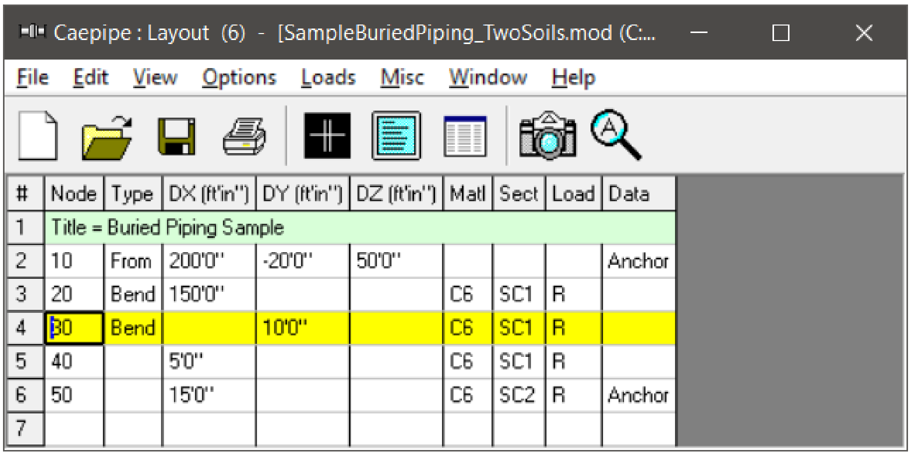
#	Name	Type	Density (lb/ft3)	Strength (psi)	Delta (deg)	Ks	Ground Level (ft'in")	Include Ins. Thk	Depth of Soil (ft'in")
1	S1	Cohesive	150	100			3'0"	No	
2	S2	Cohesive	180	120			3'0"	No	

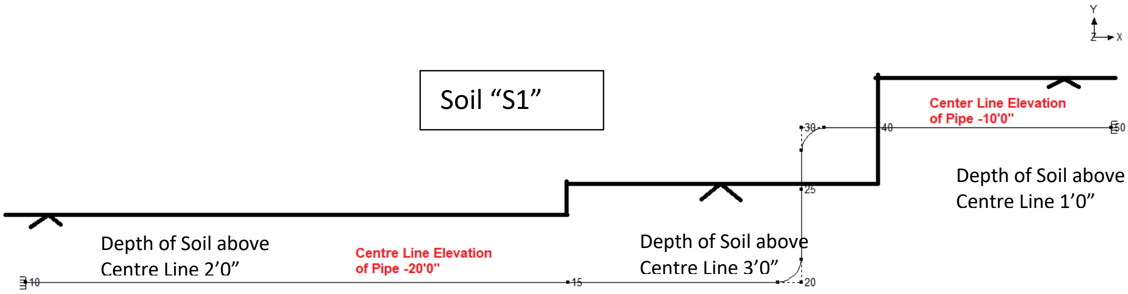


#	Name	Nom Dia	Sch	OD (inch)	Thk (inch)	Cor.Al (inch)	M.Tol (%)	Ins.Dens (lb/ft3)	Ins.Thk (inch)	Lin.Dens (lb/ft3)	Lin.Thk (inch)	Soil
1	SC1	12"	STD	12.75	0.375							S1
2	SC2	12"	STD	12.75	0.375							S2



#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Buried Piping Sample								
2	10	From	200'0"	-20'0"	50'0"				Anchor
3	20	Bend	150'0"			C6	SC1	R	
4	30	Bend		10'0"		C6	SC1	R	
5	40		5'0"			C6	SC1	R	
6	50		15'0"			C6	SC2	R	Anchor
7									

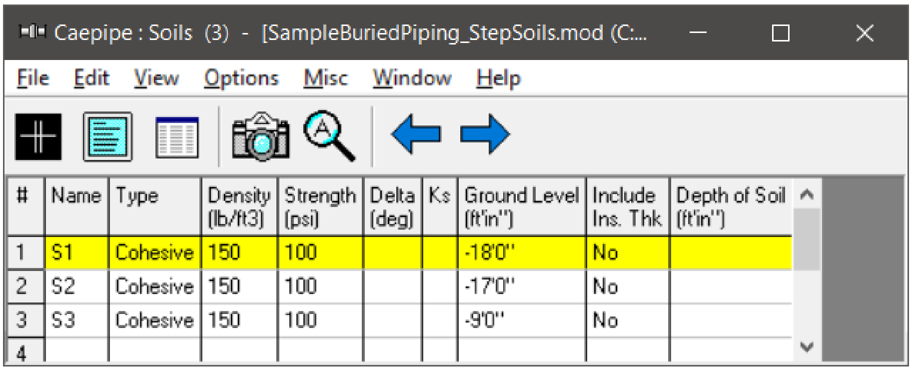
Case 3: Depth of soil above pipe centre lines are varying for the stress layout



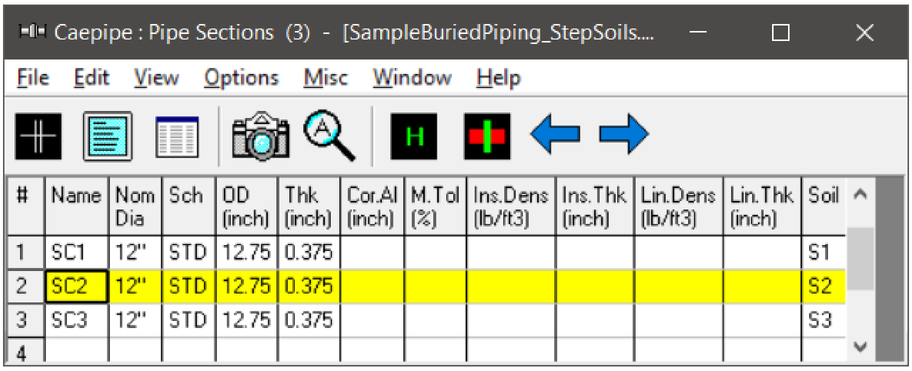
In the Figure shown above, 12" Schedule STD piping is assumed to be buried under same type of soil with depth of soil above centre line is varying for the stress layout as given above.

To represent this scenario in CAEPIPE follow the steps given below.

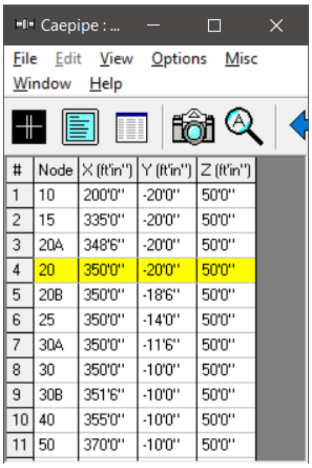
1. Define three (3) section cards "SC1", "SC2" and "SC3" with same Nominal Size as 12" and Schedule as STD.
2. Generate the layout as shown in the attached model "SampleBuriedPiping_StepSoils.mod".
3. From the Coordinate list of CAEPIPE (can be seen through Layout Window > View > List > Coordinate), calculate the Ground Level for Nodes 10 and 15. For this example, Ground Level is -18'0" (= Y Coordinate for Node 10 + Soil Depth = -20'0" + 2'0").
4. Follow Step 3 and calculate the Ground Levels above Nodes 20 and 40. For this example, it is -17'0" and -9'0" respectively.
5. Define three (3) soils "S1", "S2" and "S3" with Ground Levels as -18'0", 17'0" and -9'0" respectively and associate "S1" with "SC1", "S2" with "SC2" and "S3" with "SC3" as shown in the attached model "SampleBuriedPiping_StepSoils.mod".
6. Save the model and perform the analysis.



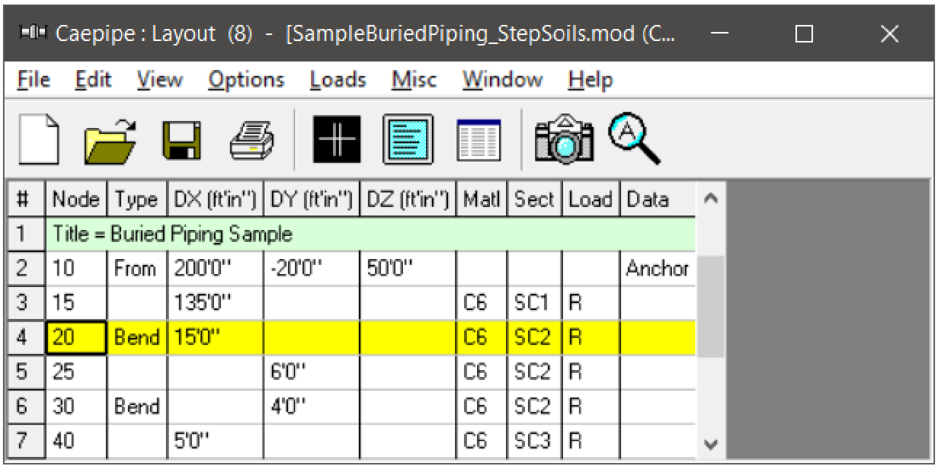
#	Name	Type	Density (lb/ft3)	Strength (psi)	Delta (deg)	Ks	Ground Level (ft'in")	Include Ins. Thk	Depth of Soil (ft'in")
1	S1	Cohesive	150	100			-18'0"	No	
2	S2	Cohesive	150	100			-17'0"	No	
3	S3	Cohesive	150	100			-9'0"	No	
4									



#	Name	Nom Dia	Sch	OD (inch)	Thk (inch)	Cor.Al (inch)	M.Tol (%)	Ins.Dens (lb/ft3)	Ins.Thk (inch)	Lin.Dens (lb/ft3)	Lin.Thk (inch)	Soil
1	SC1	12"	STD	12.75	0.375							S1
2	SC2	12"	STD	12.75	0.375							S2
3	SC3	12"	STD	12.75	0.375							S3
4												



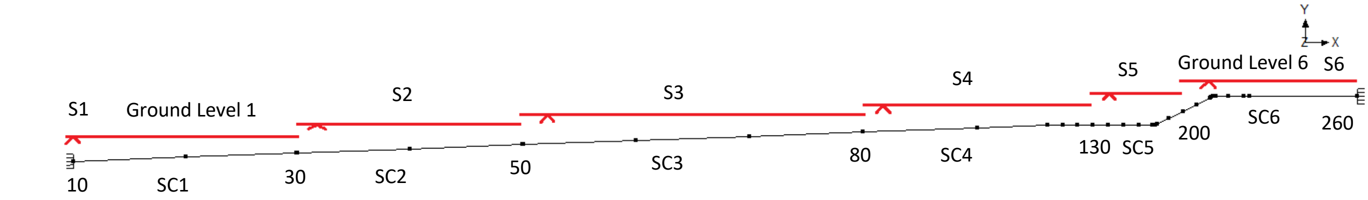
#	Node	X (ft'in")	Y (ft'in")	Z (ft'in")
1	10	200'0"	-20'0"	50'0"
2	15	335'0"	-20'0"	50'0"
3	20A	348'6"	-20'0"	50'0"
4	20	350'0"	-20'0"	50'0"
5	20B	350'0"	-18'6"	50'0"
6	25	350'0"	-14'0"	50'0"
7	30A	350'0"	-11'6"	50'0"
8	30	350'0"	-10'0"	50'0"
9	30B	351'6"	-10'0"	50'0"
10	40	355'0"	-10'0"	50'0"
11	50	370'0"	-10'0"	50'0"



#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Buried Piping Sample								
2	10	From	200'0"	-20'0"	50'0"				Anchor
3	15		135'0"			C6	SC1	R	
4	20	Bend	15'0"			C6	SC2	R	
5	25			6'0"		C6	SC2	R	
6	30	Bend		4'0"		C6	SC2	R	
7	40		5'0"			C6	SC3	R	

Case 4: Sloped line with uniform depth of Soil above Pipe Centre line

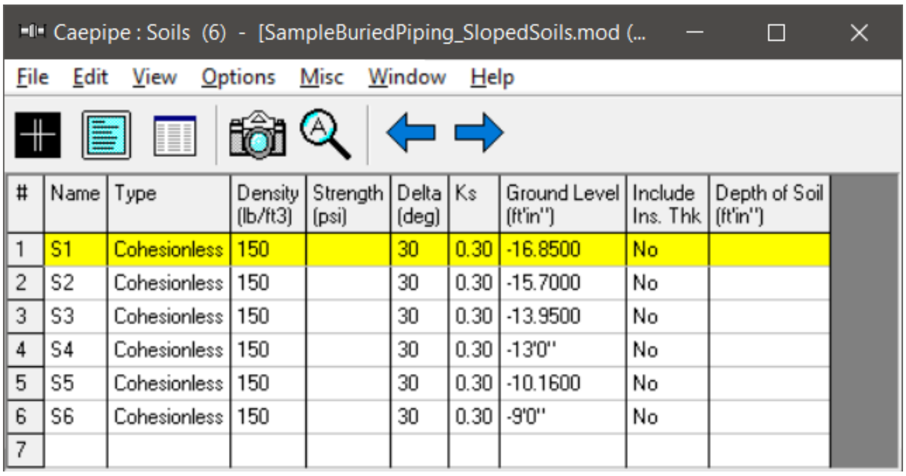
In the Figure below, 12" Schedule STD sloped line is assumed to be buried under same type of soil with depth of soil above centre line as 2' throughout the stress layout. Being a sloped line, we need to define a number of soils by changing its ground level to best simulate the field condition. In the example shown below, the stress layout is covered with six ground levels.



To represent the scenario shown above in CAEPIPE follow the steps given below.

1. Define six (6) section cards "SC1" through "SC6" with same Nominal Size as 12" and Schedule as STD.
2. Create the stress layout by defining DX, DY and DZ of each Node from Node 10 through Node 260.
3. From the Coordinate list of CAEPIPE (can be seen through Layout Window > View > List > Coordinate), calculate the Ground Level for Nodes 30, 50, 80, 130, 200 and 260. For example, add 2' to the Y coordinate of Node 30 to find its Ground Level.
4. Follow Step 3 and calculate the Ground Levels at Nodes 50, 80, 130, 200 and 260.
5. Define six (6) soils "S1" through "S6" corresponding to Nodes 30, 50, 80, 130, 200 and 260 with their Ground Levels entered as computed.
6. Associate Soils "S1" through "S6" to "SC1" through "SC6". Save the model and perform the analysis. See the attached model "SampleBuriedPiping_SlopedSoils.mod" for details.

For complex stress layout that runs on sloped terrain with uniform Depth of soil above pipe centre line, the procedure given above may become laborious at this time.


Caepipe : Soils (6) - [SampleBuriedPiping_SlopedSoils.mod (...

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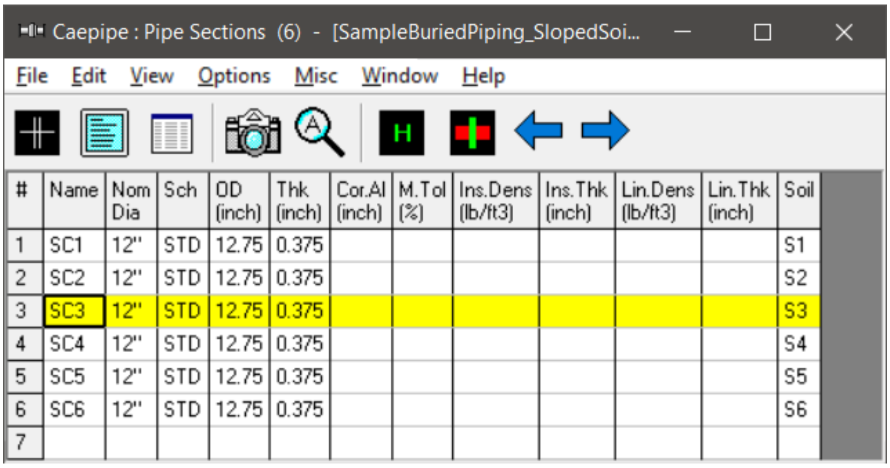
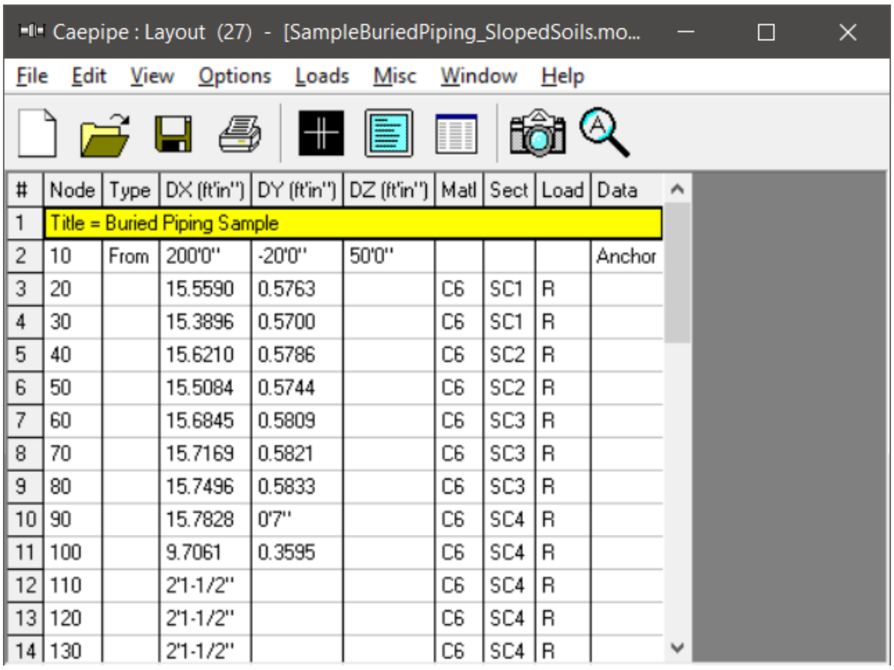
#	Name	Type	Density (lb/ft3)	Strength (psi)	Delta (deg)	Ks	Ground Level (ft'in")	Include Ins. Thk	Depth of Soil (ft'in")
1	S1	Cohesionless	150		30	0.30	-16.8500	No	
2	S2	Cohesionless	150		30	0.30	-15.7000	No	
3	S3	Cohesionless	150		30	0.30	-13.9500	No	
4	S4	Cohesionless	150		30	0.30	-13'0"	No	
5	S5	Cohesionless	150		30	0.30	-10.1600	No	
6	S6	Cohesionless	150		30	0.30	-9'0"	No	
7									



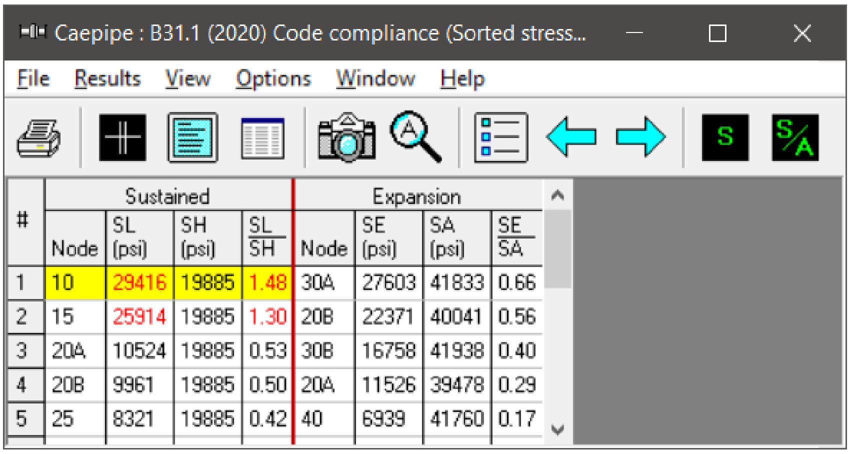
#	Name	Nom Dia	Sch	OD (inch)	Thk (inch)	Cor.Al (inch)	M.Tol (%)	Ins.Dens (lb/ft3)	Ins.Thk (inch)	Lin.Dens (lb/ft3)	Lin.Thk (inch)	Soil
1	SC1	12"	STD	12.75	0.375							S1
2	SC2	12"	STD	12.75	0.375							S2
3	SC3	12"	STD	12.75	0.375							S3
4	SC4	12"	STD	12.75	0.375							S4
5	SC5	12"	STD	12.75	0.375							S5
6	SC6	12"	STD	12.75	0.375							S6
7												



#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title = Buried Piping Sample								
2	10	From	200'0"	-20'0"	50'0"				Anchor
3	20		15.5590	0.5763		C6	SC1	R	
4	30		15.3896	0.5700		C6	SC1	R	
5	40		15.6210	0.5786		C6	SC2	R	
6	50		15.5084	0.5744		C6	SC2	R	
7	60		15.6845	0.5809		C6	SC3	R	
8	70		15.7169	0.5821		C6	SC3	R	
9	80		15.7496	0.5833		C6	SC3	R	
10	90		15.7828	0'7"		C6	SC4	R	
11	100		9.7061	0.3595		C6	SC4	R	
12	110		2'1-1/2"			C6	SC4	R	
13	120		2'1-1/2"			C6	SC4	R	
14	130		2'1-1/2"			C6	SC4	R	

For all the Cases given above, CAEPIPE will compute internally the Soil stiffnesses in three directions (axial, transverse and vertical) and apply them ONLY at node points defined in the stress layout. For further details, see the Section titled "Buried Piping" in CAEPIPE Technical Reference manual. This manual and other three (3) manuals of CAEPIPE can be downloaded from the link www.sstusa.com/caepipe-docs.php.

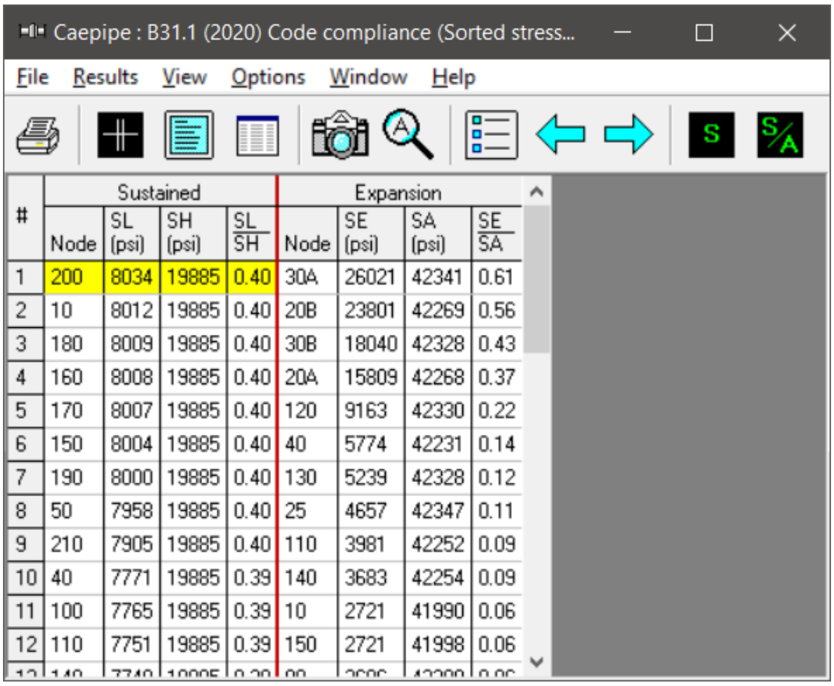
As an example, from the sorted stress results for model "SampleBuriedPiping_StepSoils.mod", you will observe that the piping is overstressed in Sustained load case as CAEPIPE applies the soil stiffnesses in three directions only at nodes defined in the stress model.



#	Sustained				Expansion			
	Node	SL (psi)	SH (psi)	SL/SH	Node	SE (psi)	SA (psi)	SE/SA
1	10	29416	19885	1.48	30A	27603	41833	0.66
2	15	25914	19885	1.30	20B	22371	40041	0.56
3	20A	10524	19885	0.53	30B	16758	41938	0.40
4	20B	9961	19885	0.50	20A	11526	39478	0.29
5	25	8321	19885	0.42	40	6939	41760	0.17

So, it is important that you should discretize the long section of the straight pipe <u>manually</u> into smaller lengths to best simulate soil to pipe interaction by following the procedure given in Buried Piping Tutorial. Long straight pipe sections can be discretized automatically using the command “Layout Window > Edit > Refine Nodal Mesh.

By discretizing the long pipe sections into smaller lengths for model “SampleBuriedPiping_StepSoils.mod” by following the procedure given in Buried Piping tutorial, you will observe that the over stresses for Sustained case is resolved. See the model “SampleBuriedPiping_StepSoils_refined.mod” for details.



#	Sustained				Expansion			
	Node	SL (psi)	SH (psi)	SL/SH	Node	SE (psi)	SA (psi)	SE/SA
1	200	8034	19885	0.40	30A	26021	42341	0.61
2	10	8012	19885	0.40	20B	23801	42269	0.56
3	180	8009	19885	0.40	30B	18040	42328	0.43
4	160	8008	19885	0.40	20A	15809	42268	0.37
5	170	8007	19885	0.40	120	9163	42330	0.22
6	150	8004	19885	0.40	40	5774	42231	0.14
7	190	8000	19885	0.40	130	5239	42328	0.12
8	50	7958	19885	0.40	25	4657	42347	0.11
9	210	7905	19885	0.40	110	3981	42252	0.09
10	40	7771	19885	0.39	140	3683	42254	0.09
11	100	7765	19885	0.39	10	2721	41990	0.06
12	110	7751	19885	0.39	150	2721	41998	0.06

Lastly, using the “Soil restraints” results of CAEPIPE (can be seen through “Results Window > Results > Results…”) you can view the Stiffness and Loads of all the elements that are buried in soil(s).