Tutorial for Buried Piping Modeling and Analysis using CAEPIPE

The following are the Steps to perform Buried Piping Modeling and Analysis using CAEPIPE.

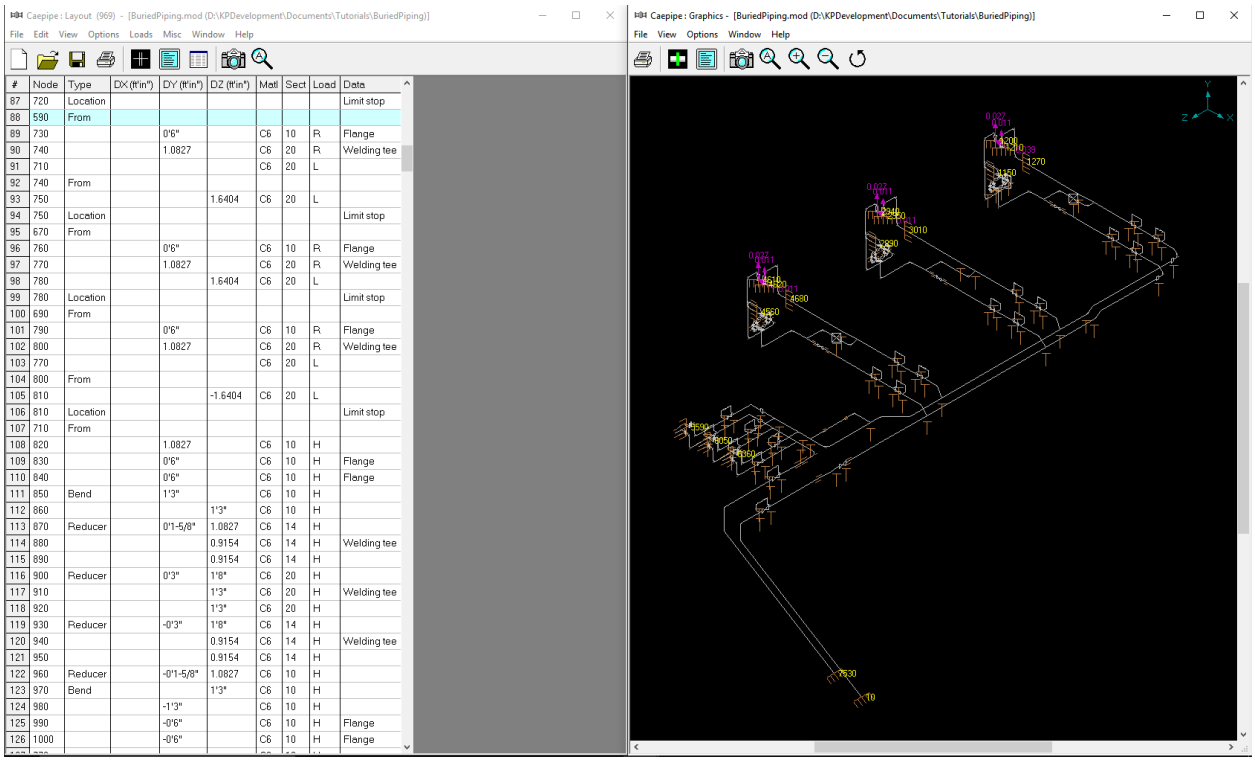
General

Soil in Buried piping analysis is modeled by using bilinear restraints with an initial stiffness and an ultimate load. After the ultimate load is reached, the displacement continues without any further increase in load, i.e., the yield stiffness is zero. The initial stiffness is calculated by dividing the ultimate load by the yield displacement which is assumed to be D/25 where D is outside diameter of the pipe.

Soil modeling is based on Winkler's soil model of infinite closely spaced elastic springs. Soil stiffness is calculated for all three directions at each node. Pressure value in the load is suitably modified to consider the effect of static overburden soil pressure. Model is analyzed for operating (W+P1+T1) condition and the displacements in the three directions are noted. A check is made for whether skin friction is mobilized and the soil has attained the yield state. If true, then the spring is released in that direction indicating that soil no longer offers resistance in that direction. This modified model is again analyzed and checked for yield stage. The iterative process is continued till the percentage difference between displacements at each node for two successive iterations is less than 1%. The final stiffness is the true resistance offered by the soil to the pipe.

Tutorial

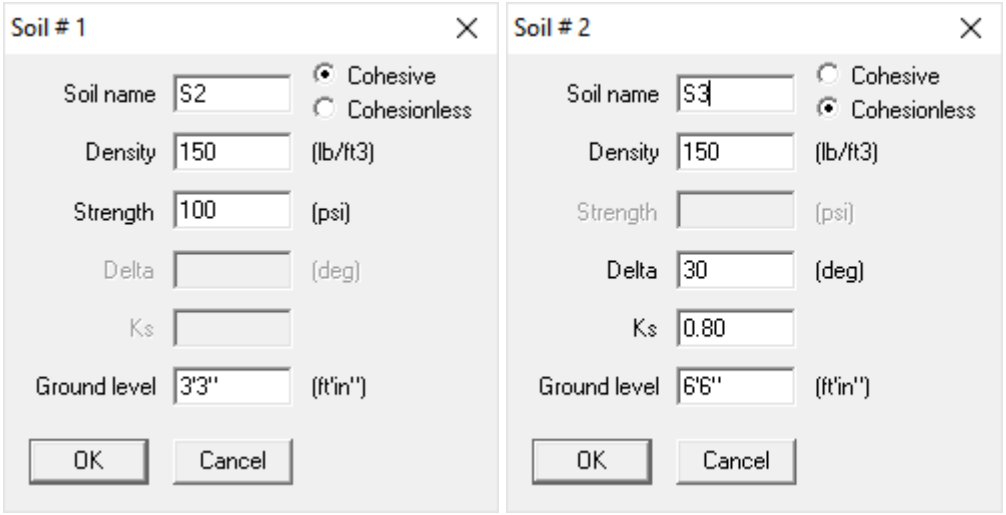
Snap shot shown below is a sample model for Buried Piping Modeling and Analysis.



#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
87	720	Location							Limit stop
88	590	From							
89	730			0'6"		C6	10	R	Flange
90	740			1.0827		C6	20	R	Welding tee
91	710					C6	20	L	
92	740	From							
93	750				1.6404	C6	20	L	
94	750	Location							Limit stop
95	670	From							
96	760			0'6"		C6	10	R	Flange
97	770			1.0827		C6	20	R	Welding tee
98	780				1.6404	C6	20	L	
99	780	Location							Limit stop
100	690	From							
101	790			0'6"		C6	10	R	Flange
102	800			1.0827		C6	20	R	Welding tee
103	770					C6	20	L	
104	800	From							
105	810				-1.6404	C6	20	L	
106	810	Location							Limit stop
107	710	From							
108	820			1.0827		C6	10	H	
109	830			0'6"		C6	10	H	Flange
110	840			0'6"		C6	10	H	Flange
111	850	Bend		1'3"		C6	10	H	
112	860				1'3"	C6	10	H	
113	870	Reducer		0'1-5/8"	1.0827	C6	14	H	
114	880				0.9154	C6	14	H	Welding tee
115	890				0.9154	C6	14	H	
116	900	Reducer		0'3"	1'8"	C6	20	H	
117	910				1'3"	C6	20	H	Welding tee
118	920				1'3"	C6	20	H	
119	930	Reducer		-0'3"	1'8"	C6	14	H	
120	940				0.9154	C6	14	H	Welding tee
121	950				0.9154	C6	14	H	
122	960	Reducer		-0'1-5/8"	1.0827	C6	10	H	
123	970	Bend			1'3"	C6	10	H	
124	980			-1'3"		C6	10	H	
125	990			-0'6"		C6	10	H	Flange
126	1000			-0'6"		C6	10	H	Flange

Step 1:

First define soils using the command Layout window > Misc > Soils.



Two types of soils can be defined - Cohesive and Cohesionless.

Cohesive soil is hard to break up when dry, and exhibits significant **cohesion** when submerged. **Cohesive soils** include clayey silt, sandy clay, silty clay, clay and organic clay.

Cohesionless soil is any free-running type of **soil**, such as sand or gravel, whose strength depends on friction between particles.

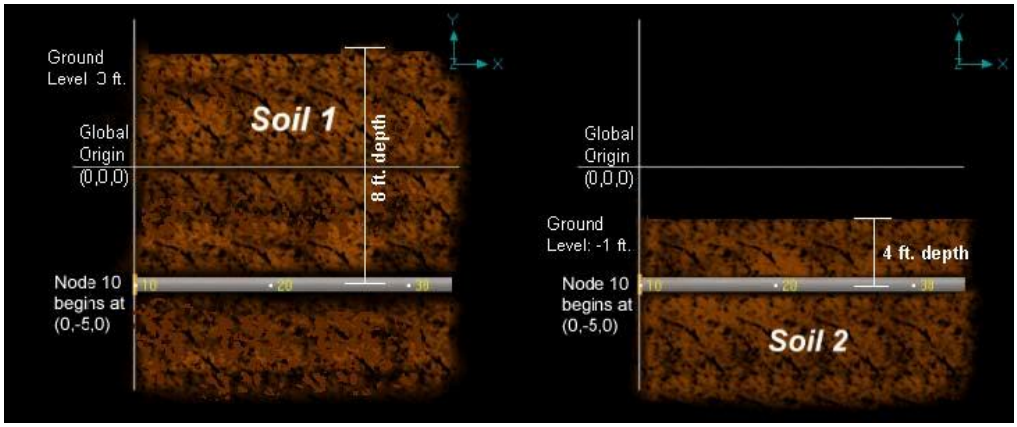
Soil density and **Ground level** are input for both cohesive and cohesionless soils. The **Ground level** is used to calculate depth of the buried section. For cohesive soil, **Strength** is the un-drained cohesive strength (Cs). For cohesionless soil, **Delta** is angle of friction between soil and pipe, and **Ks** is Coefficient of horizontal soil stress.

Ground Level

Ground level for a soil 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.

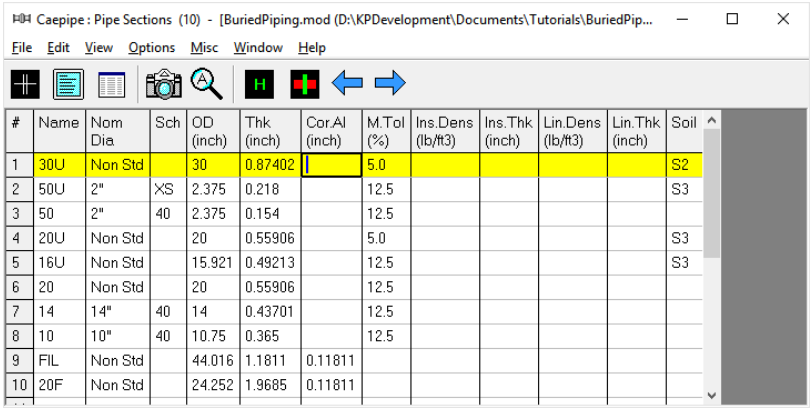
In the figure, the height of the soil surface is 3 feet from the global origin. Pipe node 10 [model origin] is defined at (0,-5, 0). So, the pipe is buried 8' (3' - [-5']) deep into the soil. Define similarly for the other soil.

The pipe centerline is calculated by CAEPIPE from the given data.

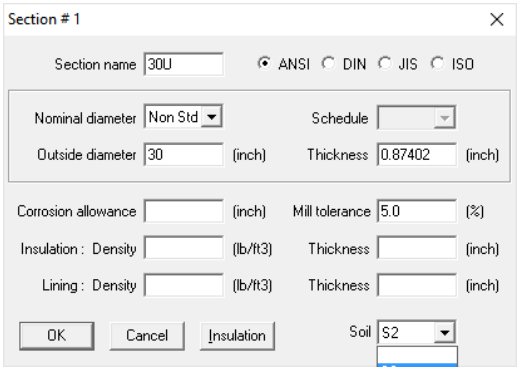


Step 2:

Tie the soils defined above with pipe sections through Layout window > Misc > Sections or Ctrl+Shft+S (to list Sections). Double click on the required section property. You will see the field Soil in the bottom right corner. Pick the soil name from the drop-down combo box.



#	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	30U	Non Std		30	0.87402		5.0					S2
2	50U	2"	XS	2.375	0.218		12.5					S3
3	50	2"	40	2.375	0.154		12.5					
4	20U	Non Std		20	0.55906		5.0					S3
5	16U	Non Std		15.921	0.49213		12.5					S3
6	20	Non Std		20	0.55906		12.5					
7	14	14"	40	14	0.43701		12.5					
8	10	10"	40	10.75	0.365		12.5					
9	FIL	Non Std		44.016	1.1811	0.11811						
10	20F	Non Std		24.252	1.9685	0.11811						



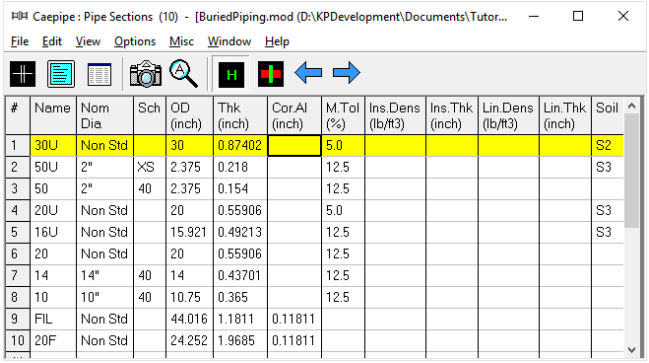
If a part of a piping system uses a certain pipe section with some portion of it buried and the balance not buried, then two separate sections have to be defined, with one of them without soil and the other with soil.

Step 3:

Use the appropriate section for each element on the Layout window that is buried with this soil around it.

Step 4:

Review the stress layout by highlighting the buried sections of the model in graphics. If your model contains sections that are above ground and buried, then you can selectively see only the buried sections of piping in CAEPIPE graphics by highlighting the section that is tied to the soil. Use the Highlight feature under the Section List window and place highlight on the buried piping section (see Highlight under List window>View menu, or press Ctrl+H). The Graphics window should highlight only that portion of the model that is using that specific section/soil. See the portion shown in green in the figure below.



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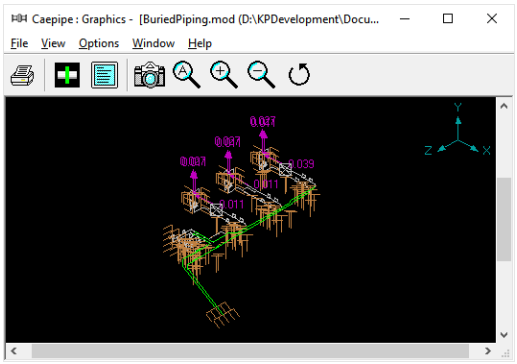
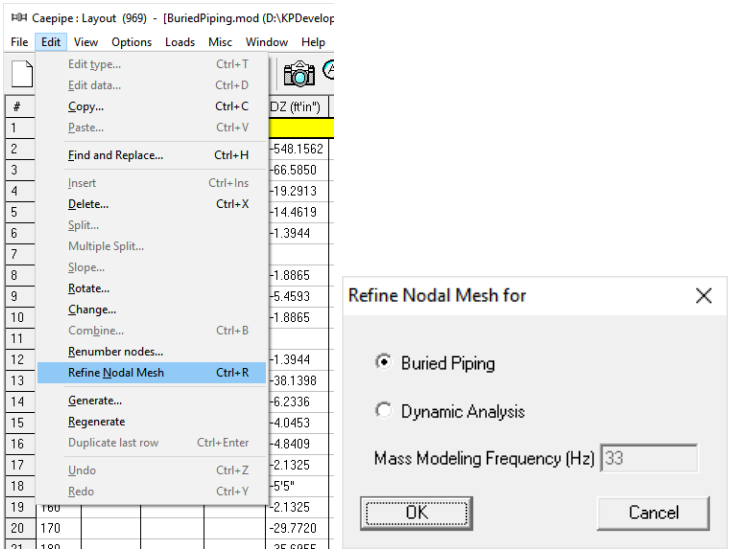


Step 5:

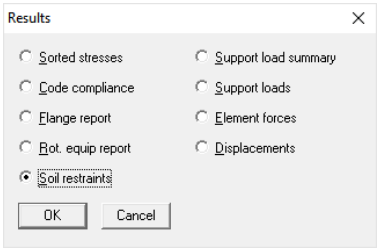
It is at the bends, elbows, and branch connections that the highest stresses are found in buried piping subjected to thermal expansion of the pipe. These stresses are due to the soil forces that bear against the transverse run. The stresses are proportional to the amount of soil deformation at the elbow or branch connection. Hence, piping elements at the junction of bends, elbows and branch connections are to be refined in the stress layout.

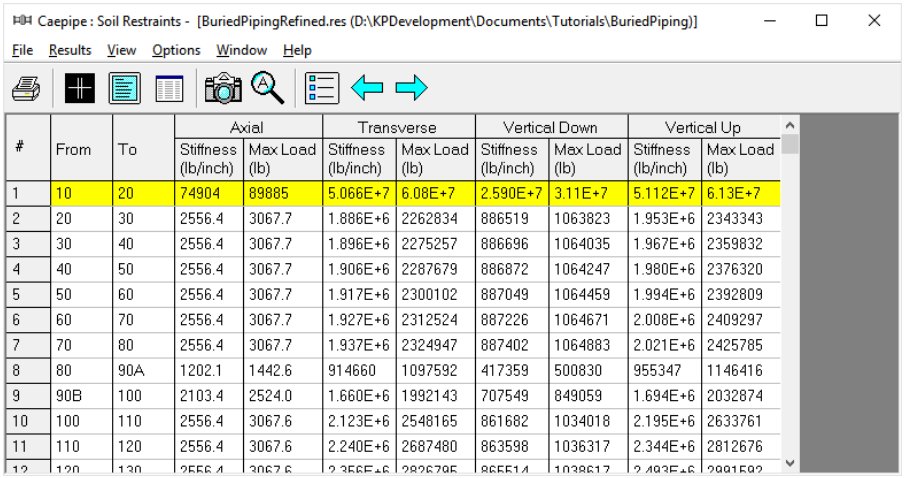
This can be performed through Layout window > Edit > Refine Nodal Mesh > Buried Piping. Please see the section titled “Buried Piping” in CAEPIPE User’s Manual for details on “Nodal mesh generation”.



Step 6:

Save the refined model as “BuriedPipingRefined.mod”. Analyze the model through File > Analyze. Upon successful analysis, CAEPIPE displays an option “Soil Restraints” in addition to other analysis results.





#	From	To	Axial		Transverse		Vertical Down		Vertical Up	
			Stiffness (lb/inch)	Max Load (lb)	Stiffness (lb/inch)	Max Load (lb)	Stiffness (lb/inch)	Max Load (lb)	Stiffness (lb/inch)	Max Load (lb)
1	10	20	74904	89885	5.066E+7	6.08E+7	2.590E+7	3.11E+7	5.112E+7	6.13E+7
2	20	30	2556.4	3067.7	1.886E+6	2262834	886519	1063823	1.953E+6	2343343
3	30	40	2556.4	3067.7	1.896E+6	2275257	886696	1064035	1.967E+6	2359832
4	40	50	2556.4	3067.7	1.906E+6	2287679	886872	1064247	1.980E+6	2376320
5	50	60	2556.4	3067.7	1.917E+6	2300102	887049	1064459	1.994E+6	2392809
6	60	70	2556.4	3067.7	1.927E+6	2312524	887226	1064671	2.008E+6	2409297
7	70	80	2556.4	3067.7	1.937E+6	2324947	887402	1064883	2.021E+6	2425785
8	80	90A	1202.1	1442.6	914660	1097592	417359	500830	955347	1146416
9	90B	100	2103.4	2524.0	1.660E+6	1992143	707549	849059	1.694E+6	2032874
10	100	110	2556.4	3067.6	2.123E+6	2548165	861682	1034018	2.195E+6	2633761
11	110	120	2556.4	3067.6	2.240E+6	2687480	863598	1036317	2.344E+6	2812676