Tutorial for Fiber Reinforced Piping (FRP) Modeling and Analysis using CAEPIPE

The following are the Steps for FRP Modeling and Analysis using CAEPIPE.

General

FRP piping has gained wide acceptance in many industries due to its lightweight nature, superior corrosion resistance, temperature capabilities and mechanical strength. Several manufacturers produce different types of FRP pipes and fittings and provide technical assistance to their customers on design matters through installation.

FRP piping can be modeled in CAEPIPE. CAEPIPE will then calculate deflections, element forces & moments, support loads and stresses.

Tutorial

Snap shot shown below is a sample model for FRP Modeling and Analysis



Step 1:

First define FRP materials required for piping system through Layout window > Misc > Materials. In the Material List window shown on the screen, double click on an empty row to input a new material or on a material description to edit the material properties.

Step 2:

In the Material dialog shown, enter the FRP material properties as given below.

Material # 1		×
Material name	FW	
Description	FRP for pipes	
Туре	FR : Fiber/Glass Reinf. Plastic (FRP)	
Density	0.064 (lb/in3)	
Nu	0.43	
Joint factor	1.00	
Yield strength	(psi)	
Tensile strength	(psi)	
ОК	Cancel Properties Library	

The material name can be up to five alpha-numeric characters. Enter description, density and Poisson's ratio. You need to select "FR: Fiber Reinf. Plastic (FRP)" from the Type drop-down combo box before you click on the Properties button.

Step 3:

Click on the Properties button, you are shown the table below where you can enter temperature-dependent properties. Additionally, you can also define the Hoop, Torsional and Axial allowable stresses so that CAEPIPE can use them to compare with calculated stresses under the FRP "Sorted Stresses" results.

Mat	terial P	roperties						×
#	Temp (F)	Axial Mod. (psi)	Hoop Mod. (psi)	Shear Mod. (psi)	Alpha (in/in/F)	Hoop All. (psi)	Torsional All. (psi)	Axial All. (psi)
1	70	1.30E+6	2.00E+6	1.20E+6	16.30E-6	3191	1450	3191
2	125	1.30E+6	2.00E+6	1.20E+6	16.30E-6	3191	1450	3191
3	392	1.30E+6	2.00E+6	1.20E+6	5.74E-6	3191	1450	3191
4								
	OK	Car	ncel					

FRP Material Moduli

CAEPIPE requires three moduli for the FRP material:



- Axial or Longitudinal (this is the most important one)
- Hoop (used in Bourdon effect calculations). If this modulus is not available, use axial modulus.

• Shear or Torsional. If this modulus is not available, use engineering judgment in specifying 1/2 of axial modulus or a similar value. Note that a high modulus will result in high stresses, and a low modulus will result in high deflections.

For FRP bends, a Flexibility factor of 1.0 is used unless you override it by specifying a Flexibility factor inside the bend dialog. Also, for FRP bends, CAEPIPE uses a default SIF of 2.3. You can override this too by specifying User-SIFs at the bend end nodes (A and B nodes).

Step 4:

After defining the FRP material properties, Section Properties and Loads required for the stress analysis, complete the stress layout. Save the model and Analyze through Layout window > File > Analyze.

Step 5:

Upon successful analysis, CAEPIPE will show the calculated stresses, deflections, support loads, element forces and support load summary. Each item can be seen under the respective title in Results. FRP element stresses can be seen, sorted or unsorted.

HIN	Caepipe :	Sorted FF	RP stresse	es: Operati	ing (W+P	1+T1) - [f	rp_piping	g.res (c:\ti	utorials\08	3_frp_pipir	ng)]						×
File	Results	View	Options	Window	Help												
4	+			6	\ E	= 🔶		\equiv		► S	^S ∕A						
		Ho	ор			Maxl	Long			Min L	ong			Tor	sion		
#	Node	Stress (psi)	Allow (psi)	Stress/ Allow	Node	Stress (psi)	Allow (psi)	Stress/ Allow	Node	Stress (psi)	Allow (psi)	Stress/ Allow	Node	Stress (psi)	Allow (psi)	Stress/ Allow	/
1	20	3537	3191	1.11	110	12925	3191	4.05	110	-10994	3191	3.45	1110	1041	1450	0.72	
2	20	3537	3191	1.11	1160B	3832	1450	2.64	1160B	-2968	1450	2.05	1100	1041	1450	0.72	
3	30	3537	3191	1.11	40A	3498	1450	2.41	40A	-2658	1450	1.83	1140	696	1450	0.48	
4	1560	3537	3191	1.11	1160A	2940	1450	2.03	110	-4964	3191	1.56	1120	696	1450	0.48	
5	1210	3537	3191	1.11	160	5930	3191	1.86	160	-4553	3191	1.43	1130	696	1450	0.48	
6	1280	3537	3191	1.11	38	5557	3191	1.74	120	-4372	3191	1.37	1145	696	1450	0.48	
7	300	3537	3191	1.11	38	5557	3191	1.74	1160A	-1899	1450	1.31	1150B	666	1450	0.46	
8	250	3537	3191	1.11	230	5391	3191	1.69	160	-3842	3191	1.20	1155	666	1450	0.46	
9	32	3537	3191	1.11	1170	5218	3191	1.64	100	-3782	3191	1.19	1110	508	1450	0.35	
10	1235	3537	3191	1.11	1150A	2221	1450	1.53	90	-3711	3191	1.16	2010	332	1450	0.23	
11	35	3537	3191	1.11	210	4792	3191	1.50	38	-3653	3191	1.14	2000	332	1450	0.23	
12	290	3537	3191	1.11	1790A	2134	1450	1.47	38	-3653	3191	1.14	2120	323	1450	0.22	_
File	Caepipe : Results	FRP stress View C	es: Opera	uting (W+F Window	21+T1) - Help	(frp_piping	j.res (c:\tu	utorials\08	3_frp_pipir	ıg)]	-	D	×				
8				<u>j</u> 🔍	、 🛅					•							
#	Node	Hoop (psi)	Axial (psi)	Bend (psi)	ing Lon Ma	gitudinal < (psi)	Longitu Min (ps	udinal T si) (p	orsional osi)	1							
1	10 20	3537 3537	-1408 -1408	33 21	-137 -138	75 37	-1441 -1429	0									
2	20 30	3537 3537	952 952	2696 1297	364 224	8 9	-1744 -345	8	D D								
3	32 35	3537 3537	952 952	412 1992	136 294	4 4	540 -1040	8	D D								
4	35 38	3537 3537	952 952	1992 4605	294 555	4 7	-1040 -3653	8	D D								
5	38 39	3537 3537	952 952	4605 3296	555 424	7 8	-3653 -2344	8	D D								
6	40A 40B	1504 1504	420 588	3078 1531	349 211	8 9	-2658 -943	3	2 5								
7	40B 50	3537 3537	1366 1366	1639 448	300 181	6 4	-273 918	3	6								
8	50 co	3537 2527	1366	448	181	4	918 000	3	6								

1 -0- 1 (Caepipe :	Displacem	ents: Oper	ating (W+	P1+T1) - [f	rp_piping.	r	- 0	×		Caepipe	e : Loac	ds on An	chors: Ope	ating (W+	•P1+T1	1) - [frp_p	ipi			×
File	Results	View C	ptions V	/indow H	lelp					File	Result	ts Vie	w Opt	ions Win	dow He	lp					
4	+			<u>)</u> Q		⇐╡	> [≣ ←	• ->	4	3 🖿				\mathbb{Q}		(-	⇒∣	\equiv	+	→
#				Displace	ements (g	lobal)		_		#	Node	Tag	FX (lb)	FY (lb) FZ (b)	MX (ft-lb)	I MY (i	ft-lb)	MZ (ft-I	o)
	Node	X (inch)	Y (inch)	Z (inch	i) 🔀 (d	leg) YY i	(deg)	ZZ (deg)	- 1	1	10		1	-426	6293	39	-205	0		0	
1	10	0.000	0.000	0.000	0.000	0.00	000	0.0000		2	20		-7969	-2406	-467	65	-4152	2635	7	1580	
2	20	0.000	0.000	0.000	0.000	0.00	000	0.0000		3	590		-19	791	-197	3	-431	-4		-261	
3	30	-0.067	-0.011	-0.050	-0.02	30 0.17	23	0.0086		4	890		-14	234	309		-205	-6		-65	
4	32	-0.092	-0.014	-0.068	-0.02	31 0.17	25	0.0087		5	990		-9	214	404		-197	-5		-3	
5	35	-0.198	-0.026	-0.129	-0.01	14 0.06	682	0.0191		6	1090		-4	295	64		-229	-2		14	
6	38	-0.211	-0.028	-0.153	-0.00	54 -0.0	476	0.0232		7	1100		-1323	577	-103	4	-259	-1005	5	-4503	
7	39	-0.206	-0.028	-0.164	-0.00	30 -0.1	169	0.0251		8	1410		6	-1094	-447		-1184	0		-18	
8	40A	-0.206	-0.028	-0.164	-0.00	30 -0.1	170	0.0251		9	1510		-3	-1083	-438		-1162	2		12	
9	40B	-0.045	-0.013	-0.134	-0.00	52 -0.2	620	0.0321		10	1710		-2	-1067	-419		-1093	3		12	
10	50	-0.026	-0.007	-0.078	-0.00	65 -0.2	952	0.0285		11	1910		2	-1061	-416		-1088	-4		-13	
11	60	-0.013	-0.003	-0.038	-0.00	73 -0.2	953	0.0239		12	2000		235	1235	-508		-315	337		1436	
12	70	0.000	0.000	0.000	-0.00	82 -0.2	778	0.0174													
1.1.0	190	I -0 001	0.001	0.053	-0.00	99 -0.2	238	0.0055													
	00	0.001						1	-												
13									-											-	
3 FIIT (Caepipe :	FRP forces	in local co	ordinates:	Operating	(W+P1+T1	1 ·	- 0	×)=()=(Caepipe	e : Supp	port load	summary	for anchor	at noc	de 10 - [fr	p	-		×
File	Caepipe : Results	FRP forces	in local co	ordinates: /indow H	Operating lelp	(W+P1+T1	1	- 0	×	+II+ File	Caepipe Result	e : Supp ts Vie	port load	summary t	for anchor	at noc	de 10 - [fr	p	_	0	×
File	Caepipe : Results	FRP forces	in local co ptions W	ordinates: /indow F	Operating lelp	(W+P1+T1	1 ·	- •	×	File	Caepipe Result	e : Supp ts Vie	port load w Opt	summary i	for anchor dow Hel	p	de 10 - [fr	₽ →	-		×
File	Caepipe : Results	FRP forces View O	in local co ptions W	ordinates: /indow H	Operating Ielp	(W+P1+T1	1 ·	- D	×	File	Caepipe Result	e : Supp ts Vie	port load	summary tions Wind	for anchor dow Hel	p	de 10 - [fr	₽	-		×
File	Caepipe : Results	FRP forces View C E Axial (lb)	in local co ptions W y Shear (lb)	ordinates: /indow F J Q z Shear (lb)	Operating Ielp	(W+P1+T1 (W-P1+T1 (W-P1+T1)) (W-P1+T1) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1)) (W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1+T1))(W-P1	1 · ▶ [: (ft-lb) SIF	- D	(ft-lb)	File	Caepipe Result	e : Supp ts Vie	port load w Opt	summary fi	for anchor dow Hel	at noc	de 10 - (fr (fr (b) M	P ➡> < (ft-lb)	-]]]		×
File	Caepipe : Results	FRP forces View C E Axial (Ib) -62939	in local co options W y Shear (Ib)	ordinates: /indow F J Q z Shear (lb)	Operating Help Torque (ft-lb)	(W+P1+T1 (W+P1+T1 Inplane(Moment	1	Outplane	(ff-lb) SIF 1.60	File Loa Sus	Caepipe Result 3 ad comb	e : Supp ts Vie	port load w Opt	summary i ions Win] E	for anchor dow Hel (A) FY (Ib) -426	FZ (de 10 - [fr (h) Mi -2	P → × (ft-lb) 05	- MY (×
13 File	Caepipe : Results Node 10 20	FRP forces View C Axial (lb) -62939 -62939	y Shear (Ib) -409 409	ordinates: /indow F I Q z Shear (Ib) 1 1 2062	Operating Help Torque (ft-lb) 0	(W+P1+T1 (W+P1+T1 Inplane(Moment -205 -206 4259	1 (ft-lb) SIF 1.60	Outplane Moment	× (ft-lb) SIF 1.60	File Loa Opi	Caepipe Result	e : Supp ts Vie	port load	summary i ions Win i i i i i i	for anchor dow Hel Q FY (lb) -426 -426	at noc p FZ (0 6293	de 10 - [fr (b) M. -2 39 -2	P → × (ft-lb) 05 05	- MY (0 0	(t+lb) N 0	×
13 File # 1	Caepipe : Results Node 10 20 30	FRP forces View C E Axial (lb) -62939 -62939 -16174 -16174	in local co ptions W y Shear (lb) -409 409 -1997 -1371	ordinates: /indow F 2 Shear (lb) 1 1 -7967 -7967	Operating Help Torque (ft-lb) 0 0 -1580 -1580	(W+P1+T' (W+P1+T' Inplane(Moment -205 -206 -4358 -482	1 • • [: (ft-lb) SIF 1.60	- C Outplane Moment 0 3 26360 8018	(ft-lb) SIF 1.60	File Loa Sus Opi	Caepipe Result ad comb stained erating1 stained	e : Supp ts Vie	port load	summary i ions Wini] E X (lb)] 1 36	for anchor dow Hel PY (lb) -426 -408	at noc p FZ (0 6293 36	lb) M(-2) 39 -2	P → < (ft-lb) 05 05 37	- → MY(0 0 17 47		×
13 File # 1 2 3	Caepipe : Results Node 10 20 30 32	FRP forces View C (b) -62939 -16174 -16174 -16174	in local co ptions W y Shear (lb) -1997 -1371 -760	ordinates: /indow P 2 Shear (lb) 1 1 -7967 -7967 -7967	Operating lelp Torque (ft-lb) 0 0 -1580 -1580 -1580	(W+P1+T1 (W+P1+T1 Inplane(Moment -205 -206 -4358 -482 251	1 (ft-lb) SIF 1.60 1.60	- Cutplane Moment 0 3 26360 8018 2541	(ff-lb) SIF 1.60 1.60	File File Loa Sus Opt Sus	Caepipe Result ad comb stained erating1 stained- stained-	e : Supp ts Vie binatio	port load w Opt	summary ions Win [] É©Î [× (lb)] [] [] [] [] [] [] [] [] [] [] [] [] [for anchor dow Hel PY (lb) -426 -426 -408 -444	FZ (0 6293 36 -36	He 10 - [fr (h) ML -2 39 -2 -1 -1 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2	P → × (ft-lb) 05 05 05 07 14	- MY(0 17 -17 17		× 1Z (₩-1b)
13 File # 1 2	Caepipe : Results Node 10 20 30 32 35	FRP forces View C Axial ((b) -62939 -62939 -16174 -16174 -16174 -16174	in local co ptions W y Shear (lb) -1997 -1371 -760 -1	ordinates: /indow F 2 Shear (lb) 1 -7967 -7967 -7967 -7967 -7967	Operating Help Torque (ft-lb) 0 0 -1580 -1580 -1580 -1580	(W+P1+T1 (W+P1+T1 Inplane(Moment -205 -206 -4358 -482 251 1313	1 (t-lb) (t-lb) SIF 1.60 1.60	Outplane Moment 0 3 26360 8018 2541 -19702	(ft-lb) SIF 1.60 1.60	File Loa Sus Opr Sus Sus	Caepipe Result ad comb stained erating1 stained- stained- stained-	e : Supp ts Vie binatio	port load w Opt	summary ions Win	for anchor dow Hel A FY (lb) -426 -426 -408 -444 -408	FZ (0 6293 36 -36 6293	de 10 - (fr (b) Mi -2 39 -2 -1 -2 74 -1 -2 -2 -1	P Y (ft-lb) D5 D5 37 14 37 14	- MY(0 17 -17 17		
13 +I+ File # 1 2 3 4	Caepipe : Results Node 10 20 30 32 35 35 30	FRP forces View C Axiel (lb) -62939 -62939 -62939 -16174 -16174 -16174 -16174 -16174	in local co ptions W y Shear (lb) -409 -1997 -1371 -760 -1 -7	ordinates: /indow P 2 Shear (lb) 1 1 -7967 -7967 -7967 -7967 -7967 -7967 -7967	Operating telp Torque (ft-lb) 0 0 -1580 -1580 -1580 -1580	(W+P1+TT Inplane(Moment -205 -206 -4358 -482 251 1313 1313 1314	(t-lb) SIF 1.60 1.60	- Outplane Moment 0 3 26360 8018 2541 -19702 -19702 -29400	(#Hb) SIF 1.60 1.60	File File Loa Sus Opt Sus Opt	Caepipe Result ad coml stained erating1 stained- stained- stained- erating1	e : Supp ts Vie binatio 1 +Seisr 1+Seisr 1-Seiss	port load w Opt	summary 1 ions Win (b) (b) (c) (c) (c) (c) (c) (c) (c) (c) (c) (c	for anchor dow Hel	P FZ (0 6293 36 -36 6293 6293	de 10 - [fri [b] Mt -2: 39 -2: 39 -2: -1: -2: 74 -1: 03 -2: 74 -1: 03 -2: 74 -1: 03 -2: 74 -1: 03 -2: 74 -1: 03 -2: 74 -1: 03 -2: 74 -1: 03 -2: 75 -2: 7	P × (ft-lb) 05 05 37 14 37 14 37 14	− MY (0 0 17 -17 17 -18 12		× 42 (tt-1b)
13 File # 1 2 3 4	Caepipe : Results Node 10 20 30 32 35 38 38 38	FRP forces View C Axial (lb) -62939 -16174 -16174 -16174 -16174 -16174 -16174	in local co ptions W y Shear (lb) -409 -1997 -1371 -760 -1 -1 299 354	ordinates: indow P 2 Shear (b) 1 -7967 -7067	Operating ielp Torque (ft-lb) 0 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580	(W+P1+T) (W+P1+T) Inplane(Moment -205	(t -lb) (t-lb)(Outplane Moment 0 3 26360 8018 2541 -19702 -28499 -28499	(#-Ib) SIF 1.60 1.60 1.60	File File Sus Op Sus Sus Sus Sus Sus	Caepipe Result ad comb stained erating 1 stained- stained- stained- erating 1 stained- stained- stained- stained- stained- erating 1	e:Supp ts Vie binatio 1 +Seism 1+Seis 1-Seisi	port load w Opt	summary ions Win (b) (b) (b) (c) (c) (c) (c) (c) (c) (c) (c	for anchor dow Hel PY (lb) -426 -426 -426 -408 -444 -408 -444 -408 -444	at noc p FZ (0 6293 36 6293 6294 6295	de 10 - [fri [b] M(-2) 339 -2) -2) -2) -2) -2) -2) -2) -2)	P × (ft-lb) 05 05 05 07 14 37 14 37 14	- MY(0 0 17 -17 17 -18 17 -18		×
13 File # 1 2 3 4 5	Caepipe : Results Node 10 20 30 32 35 38 38 39	FRP forces View C Axial (lb) -62939 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174	in local co ptions W y Shear (lb) -409 409 -1397 -1371 -760 -1 -1 299 354 495	ordinates: indow P 2 Shear (b) 1 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967	Operating telp Torque (ft-lb) 0 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580	(W+P1+T) (W+P1+T) Inplane(Moment -205	1 (1.60 1.60 1.60 1.60	Outplane Moment 0 3 26360 8018 2541 -19702 -28499 -28499 -28499 -32649	(ft-lb) SIF 1.60 1.60 1.60 1.60	File File Loa Sus Sus Sus Sus Sus Sus Sus Sus Sus Sus	Caepipe Result ad comb stained erating1 stained- stained- erating1 erating1 erating1 erating1	e : Supp ts Vie binatio 1 +Seisr 1+Seis 1-Seisi	oprt load w Opt	summary i ions Wini inf (b) i i i i i i i i i i i i i i i i i i i	FY (lb) -426 -426 -426 -426 -444 -408 -444 -408 -444 0	at noc p FZ (0 6293 6293 6294 6294 6294 6294 6294 6294 6294 6294	le 10 - [fri (b) Mt -22 39 -22 39 -22 39 -22 39 -22 74 -11 03 -2 74 -11 03 -2 74 -11 0 -2 74 -11 0 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2	P × (ft-lb) 05 05 37 14 37 14 37 14	- - - - - - - - - - - - - -		× 4Z (ft-1b)
13 File # 1 2 3 4 5 6	Caepipe : Results Node 10 20 20 32 35 35 38 38 39 40A	FRP forces View C Axial (lb) -62939 -62939 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174	in local co pptions W y Shear (lb) -1097 -1371 -760 -1 -1 299 354 495 -7967	ordinates: (indow P 2 Shear (b) 1 -7967 -7957	Operating telp Torque (ft-lb) 0 0 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580	(W+P1+T) (W+P1+T) Inplane(Moment -205	1 • • [[[[[[[[[[[[[[[[Outplane Moment 0 3 26360 8018 2541 -19702 -28499 -28499 -28499 -32649 927	(ft-lb) SIF 1.60 1.60 1.60 1.60 2.30	File File Sus Sus Sus Sus Sus Min Allo	Caepipe Result ad comb stained erating1 stained- stained- stained- stained- stained- istained- stained- stained- stained- stained- erating1 erating1 erating1 erating1 erating1	e : Supp ts Vie binatio 1 +Seisr -Seisr 1-Seisr -Seisr s	port load w Opt	summary i ions Win (b) (b) (b) (c) (c) (c) (c) (c) (c) (c) (c	or anchor dow Hel (b) -426 -426 -426 -426 -426 -428 -444 -408 -444 -408 -444 0	at noc p FZ (0 6293 36 6293 6293 6294 6295 6295 6295 6295 6295 6295 6295 6295 6295 6295 6295 6295	le 10 - [fri [b] Mt -2 39 -2 -2 39 -2 -1 -2 74 -1 0 -2 74 -1 -2 74 -1 0 0	P × (ft-lb) 05 05 05 05 07 14 07 14 07 14	- - - - - - - - - - - - - -		×
13 File # 1 2 3 4 5 6	Caepipe : Results Node 10 20 20 32 35 35 38 38 39 40A 40B	FRP forces View C Axial (b) -62939 -62939 -62939 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174 -16174	in local co pptions W y Shear (lb) -1097 -1371 -760 -1 -1 299 354 495 -7967 16174	ordinates: (indow P 2 Shear (b) 1 -7967	Operating telp Torque (ft-lb) 0 -1580	(W+P1+T) Inplane(Moment -205 -2	I Г (н. Ib) SIF 1.60 1.60 1.60 2.30 2.30	Outplane Moment 0 3 26360 8018 2541 -19702 -28499 -28499 -28499 927 -32649	(ft-lb) SIF 1.60 1.60 1.60 1.60 2.30 2.30	File File Sus Sus Sus Sus Sus Op Op Op Main Allo	Caepipe Result Ad comb stained stained stained erating stained erating ximum iimum iimum	e : Supp ts Vie binatio 1 +Seisrr 1-Seisr 1-Seiss	port load	summary i ions Win (b) (b) (c) (c) (c) (c) (c) (c) (c) (c) (c) (c	or anchor dow Hel (b) -426 -426 -426 -426 -408 -444 -408 -444 -408 -444 0	P FZ (0 629: 36 -36 629: 429: 429: 629:	le 10 - [fri [b] Mt -2 39 -2 -2 39 -2 -1 -2 74 -1 0 -2 74 -1 -2 0 -2 0	P ((t-lb)) ((t-lb))	- - - - - - - - - - - - - -	(H-H) (H) (H) (H) (H) (H) (H) (H) (H) (H) (×
13 •III File # 1 2 3 4 5 6 7	Caepipe : Results Node 10 20 20 30 32 35 35 38 38 39 40A 40B 40B 50	FRP forces View C FRP forces View C FRP forces C C C C C C C C C C C C C	in local co pptions W y Shear (lb) -1997 -1371 -760 -1 -1 299 354 495 -7967 16174 1403	ordinates: (indow P 2 Shear (b) 1 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -7967 -1403 16174	Operating telp Torque (tt-lb) 0 0 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -1580 -723 -723	(W+P1+T) Inplane(Moment -205 -2	1 (t -lb) SIF 1.60 1.60 1.60 1.60 2.30 2.30	Outplane Moment 0 3 26360 8018 2541 -19702 -19702 -28499 -28499 -28499 -32649 927 -566 -16236 -11236	× (tt-lb) SIF 1.60 1.60 1.60 1.60 2.30 2.30	File File Sus Op Sus Sus Sus Sus Allc	Caepiper Result ad comH ad com	e : Supp ts Vie binatio 1 +Seisr 1-Seiss 1-Seiss	port load	summary i ions Win (b) (b) (c) (c) (c) (c) (c) (c) (c) (c) (c) (c	or anchor dow Hel (b) -426 -426 -426 -426 -408 -444 -408 -444 -408 -444 0	P FZ (0 6293 6293 6293 6294 6295 6294 6295 6295 6295 6295 6295 6295 6295 6295 6295 6295	de 10 - [fri (b) MC -22 39 -22 39 -22 39 -22 -11 -22 74 -11 03 -22 74 -11 03 -22 74 -11 0 0 0	P ≺ (ft-lb) 05 05 05 05 05 05 14 37 14 37 14 14 14	- MY (0 0 17 -17 17 -18 17 -18 0 -18 0 -18		× 4Z (ft-1b)

Stiffness matrix formulated internally in CAEPIPE and the formulas used for computing different stresses are given below for quick reference.

Stiffness matrix

The stiffness matrix for a pipe is calculated using the following terms:

Axial term = L / EA

Shear term = shape factor x L / GA

Bending term = L / EI

Torsion term = L / 2GI

where L = length, A = area, I = moment of inertia, E = elastic modulus, G = shear modulus

For an isotropic material, G = E / 2(1 + v), where v = Poisson's ratio,

For a FRP material, E = axial modulus and G is independently specified (i.e., it is not calculated using E and v).

The hoop modulus and FRP Poisson's ratio are only used in Bourdon effect calculation where,

Poisson's ratio used = FRP Poisson's ratio input x (axial modulus / hoop modulus)

FRP Stresses

Hoop stress: $S_H = \frac{PD}{2t_m}$ Axial stress: $S_A = \frac{PD}{4t_m} + \frac{F}{A}$ Bending stress: $S_B = \frac{\sqrt{(i_l M_l)^2 + (i_0 M_0)^2}}{Z}$ Torsional stress: $S_T = \frac{M_t}{2Z}$ Longitudinal maximum = Axial + Bending = $S_A + S_B$ Longitudinal Minimum = Axial – Bending = $S_A - S_B$ where P = pressure D = outside diameter t_m = minimum thickness = nominal thickness x (1 – mill tolerance/100) – corrosion allowance

- i_i = in-plane stress intensification factor
- i_o = out-of-plane stress intensification factor
- M_i = in-plane bending moment
- M_o = out-of-plane bending moment
- $M_t = torque$
- Z =section modulus
- F = axial force
- A = cross-section area