SSLL100 - Symmetrical structure of beams with an elbow

Summary:

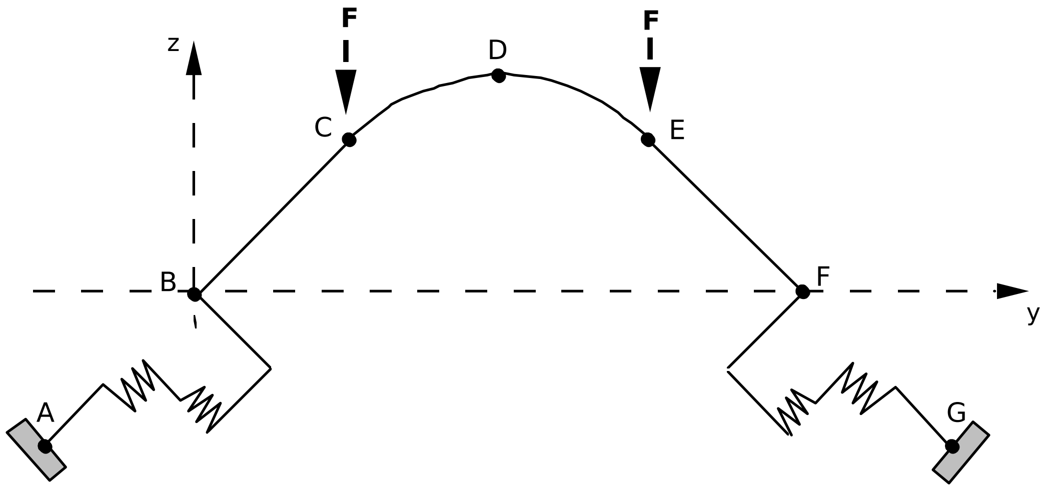
This test in statics, linear elasticity makes it possible to validate the elements of rectangular beam and curves in cross-bending, as well as the discrete elements. Four loadings are defined, of which some in local reference mark.

Two modelings make it possible to test on the one hand the right elements (the elbow is modelled using 20 right elements) and on the other hand the right and curved elements.

The reference solution is resulting from the file of validation of the code LICE (except in the case of loading 5 where it is about not-regression). Results got with *Code_Aster* are very close (lower deviation than 2.10^{-4} for the modeling of the arc of a circle with POU_C_T, a little higher variation (3%) for that with POU_D_T, which is due to a too coarse discretization).

1 Problem of reference

1.1 Geometry



Symmetrical plane structure compared to the line $y=4$.

Beams of section	circular	external diameter	$de=0.04\,m$
		internal diameter	$di=0.01\,m$
Elbow	of center	($y=4$ $z=0$)	and of ray = $2\sqrt{2}\,m$
Connection node-node		$Kx=Kz=10^5\,N/m$	in the local reference mark

Coordinates of the points (in m):

	A	B	C	D	E	F	G
x	0.	0.	0.	0.	0.	0.	0.
y	– 2.	0.	2.	4.	6.	8.	10.
z	– 2.	0.	2.	$2\sqrt{2}$	2.	0.	– 2.

1.2 Material properties

Young modulus: $E=2.1\,10^{11}\,Pa$
Poisson's ratio: $\nu=0.3$
Density: $\rho=7800.\,kg/m^3$
Thermal dilation coefficient: $\alpha=10^{-6}\,m/°C$

1.3 Boundary conditions and loadings

Points A and G embedded ($v=w=0$) (except in the case of load 2)

Loading:

1) loading concentrated in C and E — $F=1000\,N$
2) displacement imposed in A and G — $Dx=\sqrt{2}$ in local reference mark of the meshs AB and GF
3) thermal dilation with $t=100\,°C$
4) actual weight
5) material dependent on T

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is that given in the card of validation STA.MPACO/B of the code LICE of EDF R & D [bib1], except in the case of loading 5 where it is about not-regression.

2.2 Results of reference

Displacements of the points B , C and D .

2.3 Uncertainty on the solution

- modeling A : $<10^{-3}$ (finite element providing of the exact values to the nodes),
- modeling B : some $\%$ (digital solution function of the discretization).

2.4 Bibliographical references

1. Computer code of structures of beam LICE. Card of validation of module EFPOU MPACO/B - Direction of the Studies and Research E.D.F (1988)

3 Modeling A

3.1 Characteristics of modeling

6 meshs SEG2 :	2 meshs CD , CE	curved beam	POU_C_T
	2 meshs BC , EF	right beam	POU_D_T
	2 meshs AB , FG	connection element	DIS_T

Limiting conditions:

```
DDL_IMPO= _F (GROUP_NO=Poutre,          DX= 0. ,  DRY= 0. ,  DRZ= 0. )
          _F (NOEUD= ('WITH', 'G'),     DX= 0. ,  DY= 0. ,  DZ= 0.  )
```

loading case 1

```
FORCE_NODALE=_F (NOEUD= ('C', 'E'), FZ = -1000.0)
```

loading case 2 (only)

```
              (NOEUD=' A',            DX= 0. ,  DY= 1. ,   DZ= 1.  )
              (NOEUD=' G',            DX= 0. ,  DY=-1.,   DZ= 1.  )
```

loading case 3: Loading in temperature via the order AFFE_MATERIAU

```
AFFE_VARC=_F (   NOM_VARC=' TEMP', VALE_REF=0., EVOL=TEMP,
              TOUT=' OUI', NOM_CHAM=' TEMP',),)
```

loading case 4

```
PESANTEUR=_F (   GRAVITE=9.81,
              DIRECTION= (0. , 0. , - 1.))
```

loading case 5: Loading case 1 $+$ thermal loading depend on time $+$ dependence of material at the temperature

```
T ('INST', 'X', 'Y', 'Z') =2.*INST* (3.+ (4.*Y*Z) + (5.*Y*Y) + (5.*Z*Z))
T ('INST'=2) =500
T ('INST'=3) =1000
```

$$\alpha=0\ m/°C$$
$$E(T)=(1.910\mathrm{E}+4*T*T)+(9.045\mathrm{E}+7*T)+1.80005\mathrm{E}+11$$
$$\nu(T)=(-2.0\mathrm{E}-8*T*T)+(7.044\mathrm{E}-5*T)+0.2996$$

Name of the nodes: A, B, C, D, E, F
Name of the meshs: AB, BC, CD, DE, EF, FG

3.2 Characteristics of the grid

Many nodes: 7
Many meshs and types: 6 SEG2

3.3 Sizes tested and results

Case	Not	displacement (m)	Reference	*Aster*	%diff	tolerance
1 Forces nodal	B	v_B	– 8.120E-3	– 8.1201E-3	0.00	1.E-3
		w_B	– 1.000E-2	– 1.0000E-2	0.00	
	C	v_C	7.389E-3	7.3895E-3	0.00	
	D	w_D	– 2.553E-2	– 2.5530E-2	0.00	
2 Displacement imposed	B	v_B	9.858E-1	9.8585E-1	0.00	1.E-3
		w_B	1,000	1.0000	0.00	-
	C	v_C	1.738E-1	1.7382E-1	0.01	-
	D	w_D	1,812	1.8120	0.00	-
3 Dilation	B	v_B	– 5.660E-6	– 5.6597E-6	0.01	1.E-3
		w_B				
	C	v_C	– 1.305E-4	– 1.3047E-4	0.02	
	D	w_D	5.248E-4	5.2480E-4	0.00	
4 Gravity	B	v_B	– 3.111E-3	– 3.1107E-3	0.01	1.E-3
		w_B	– 4.552E-3	– 4.5522E-3	0.00	
	C	v_C	1.180E-3	1.1802E-3	0.02	
	D	w_D	– 8.850E-3	– 8.8504E-3	0.00	
5 Function of T `INST=1`	B	v_B	-8.12266E-03	-8.12368E-03	0,013	1.E-3
		w_B	-0.0100	-0.0100	0.00	
	C	v_C	9.1571E-03	9.15710E-03	0.00	
		w_C	-0.027304	-0.027304	0.00	
	E	v_E	-5.64313E-03	-5.643138E-03	0.00	
		w_E	-0.023785	-0.023785	0.00	
	F	v_F	8.12266E-03	8.123686	0,013	
		w_F	-0.0100	-0.0100	0.00	
5 Function of T `INST=2`	B	v_B	-8.10916E-03	-8.10916E-03	0.00	1.E-3
		w_B	-0.0100	-0.0100	0.00	
	C	v_C	6.62445E-03	6.6241987E-03	0,004	
		w_C	-0.0247525	-0.0247522	0.00	
	E	v_E	-6.62445E-03	-6.6242806E-03	0,003	
		w_E	-0.0247525	-0.0247523	0.00	
	F	v_F	8.10916E-03	8.10916E-03	0.00	
		w_F	-0.0100	-0.0100	0.00	

	B	v_B	-8.07655E-03	-8.076795E-03	0,003	1.E-3
5		w_B	-0.0100	-0.0100	0.00	
Function of T	C	v_C	4.96385E-03	4.973485E-03	0.19	0.21E-2
INST=3		w_C	-0.0230554	-0.0230652	0.00	1.E-3
	E	v_E	-4.96385E-03	-4.973567E-03	0.2	0.21E-2
		w_E	-0.0230554	-0.0230653	0,043	1.E-3
	F	v_F	8.07655E-03	8.0767953E-03	0,003	
		w_F	-0.01000	-0.01000	0.00	

4 Modeling B

4.1 Characteristics of modeling

The arc of beam was modelled in a polygonal line of 2×20 SEG2.

Limiting conditions:

```
        DDL_IMPO= _F (GROUP_NO=' Npoutre',   DX= 0.0, DRY= 0.0, DRZ= 0.)
                  _F (NOEUD= ('WITH', 'G),      DX= 0.0, DY= 0.0, DZ= 0. )
```

except for loading case 2

```
                    (NOEUD=' A',        DX= 0.0, DY= 1.0, DZ= 1.0)
                    (NOEUD=' G',        DX= 0.0, DY=-1.0, DZ= 1.0)
```

loading case 1

```
        FORCE_NODALE=_F (NOEUD= ('C', 'D'), Fz = -1000.0)
```

loading case 3: Loading in temperature via the order AFFE_MATERIAU

```
        AFFE_VARC=_F (   NOM_VARC=' TEMP', VALE_REF=0., EVOL=TEMP,
                    TOUT=' OUI', NOM_CHAM=' TEMP',),)
```

loading case 4

```
    PESANTEUR=_F (   GRAVITE=9.81,
                DIRECTION= (0. , 0. , - 1.))
```

Name of the nodes: A, B, C, D, E, F

4.2 Characteristics of the grid

Many nodes: 45

Many meshs and types: 44 SEG2

4.3 Sizes tested and results

Case	Not	displacement (m)	Reference	*Aster*	%diff	tolerance
	B	v_B	– 8.120E-3	– 8.1209E-3	0.01	1.E-3
1		w_B	– 1.000E-2	– 1.0000E-2	0.00	
Forces	C	v_C	7.389E-3	7.3863E-3	– 0.04	
nodal	D	w_D	– 2.553E-2	– 2.5528E-2	– 0.01	
	B	v_B	9.858E-1	9.8585E-1	– 0.00	1.E-3
2		w_B	1,000	1.0000	– 0.00	
Displacement	C	v_C	1.738E-1	1.7374E-1	– 0.04	
imposed	D	w_D	1,812	1.8121	0.	
	B	v_B	– 5.660E-6	– 5.6612E-6	0.02	1.E-3
3		w_B				

Dilation	C	v_C	– 1.305E-4	– 1.3051E-4	0.01	
	D	w_D	5.248E-4	5.2484E-4	0.01	
	B	v_B	– 3.111E-3	– 3.1145E-3	0.11	5.E-3
4		w_B	– 4.552E-3	– 4.5521E-3	0.00	
Gravity	C	v_C	1.180E-3	1.1409E-3	– 3.31	5.E-2
	D	w_D	– 8.850E-3	– 8.8148E-3	– 0.40	5.E-3

4.4 Remarks

The modeling of the elbow by right elements requires a very fine grid, for a sufficient precision (in particular for a loading distributed).

5 Summary of the results

Results got with *Code_Aster* coincide well with those of the code LICE (reference solution) in particular for modeling A (POU_C_T).

For modeling B , they are very close also ($<4.0\,10^{-4}$) except in the case of load of gravity (3% of variation to the maximum) because of the dependence of the solution to the smoothness of discretization.

This test thus validates the element POU_C_T.