SSLL100 - Symmetric structure of beams with a Summarized

elbow:

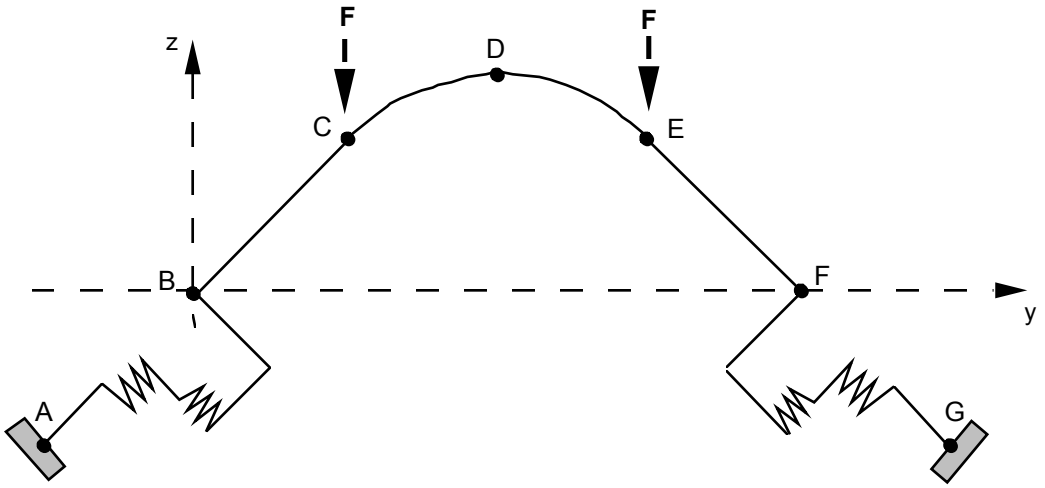
This test in static, linear elasticity makes it possible to validate the right beam elements and curves in cross-bending, as well as the discrete elements. Four loadings are defined, of which some in local coordinate system.

Two modelizations 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 NON-regression). The results got with *Code_Aster* are very close (lower deviation than 2.10^{-4} for the modelization of the arc of 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



symmetric plane Structure compared to the right $y=4.$

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

Coordinated 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

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

1.3 Boundary conditions and loadings

Points A and G clamped ($v=w=0$) (except for the loading case 2)

Loading:

1) charge concentrated in C and E $F=1000\,N$
2) displacement imposed in A and G $Dx=\sqrt{2}$ in local coordinate system of meshes AB and GF
3) thermal thermal expansion with $t=100\,°C$
4) inertia loading
5) material dependant on T

2 Reference solution

2.1 Méthode de calcul used for the reference solution

the reference solution is that given in the file 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 NON-regression.

2.2 Results of reference

Displacements of the points B , C and D .

2.3 Uncertainty on the solution

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

2.4 Bibliographical references

1.structure computer Code of beam LICE. Card-index validation of modulus EFPOU MPACO/B - Direction of the Studies and Searches E.D.F (1988) Modelization

3 A Characteristic

3.1 of the modelization 6 meshes

SEG2 : 2 meshes , curved beam CD CE POU_C_T 2 meshes
, straight beam BC EF POU_D_T 2 meshes
, limiting AB FG connection element DIS_T

Conditions: DDL_

```
   IMPO=_F ( GROUP_NO=Poutre, DX= 0        . , DRY=   0. , DRZ=   0. ) _F
(NOEUD
             = ("A", "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 command 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 the material to 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 Name
```

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

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

3.2 of the mesh Many

nodes: 7 Number of meshes
and types: 6 SEG2 Quantities

3.3 tested and Case results

Not	displacement	() Reference m	Aster	%diff	tolerance	– 8.120
	B	v_B	E-3 – 8.1201	E-3 0.00	1.E-	3 1 –
1.000		w_B	E-2 – 1.0000	E-2 0.00	Forces	
7.389	C	v_C	E-3 7.3895	E-3 0.00	nodal	
– 2.553	D	w_D	E-2 – 2.5530	E-2 0.00	9.858	
	B	v_B	E-1 9.8585	E-1 0.00	1.E-	3 2 1.000
		w_B	1.0000	0.00	- Displacement	
1.738	C	v_C	E-1 1.7382	E-1 0.01	- imposed	
1.812	D	w_D	1.8120	0.00	- –	5.660
	B	v_B	E-6 – 5.6597	E-6 0.01	1.E-	3 3 Thermal expansion
		w_B				
– 1.305	C	v_C	E-4 – 1.3047	E-4 0.02	5.248	
	D	w_D	E-4 5.2480	E-4 0.00	– 3.111	
	B	v_B	E-3 – 3.1107	E-3 0.01	1.E-	3 4 –
4.552		w_B	E-3 – 4.5522	E-3 0.00	Gravity	
1.180	C	v_C	E-3 1.1802	E-3 0.02	– 8.850	
	D	w_D	E-3 –8.8504	E-3 0.00	-8.12266	
	B	v_B	E-03 -8.12368	E-03 0.013	1.E-	3 5 -0.0100
5		w_B	-0.0100	0.00	Function	
from T 9.1571	C	v_C	E-03 9.15710	E-03 0.00	INSTS	
=1		w_C	-0.027304	0.00	-5.64313	
-0.027304	E	v_E	E-03 -5.643138	E-03 0.00	-0.023785	
		w_E	-0.023785	0.00	8.12266	
	F	v_F	E-03 8.123686	0.013	-0.0100	
		w_F	-0.0100	0.00	-8.10916	

	B	v_B	E-03 -8.10916	E-03 0.00	1.E-	3 5 -0.0100
5		w_B	-0.0100	0.00	Functio n	
from T 6.62445 =2 -0.0247525	C	v_C	E-03 6.6241987	E-03 0.004	INSTS	
		w_C	-0.0247522	0.00	-6.6244 5	
	E	v_E	E-03 -6.6242806	E-03 0.003	-0.0247 525	
		w_E	-0.0247523	0.00	8.10916	
	F	v_F	E-03 8.10916	E-03 0.00	-0.0100	
		w_F	-0.0100	0.00	-8.0765 5	
	B	v_B	E-03 -8.076795	E-03 0.003	1.E-	3 5 -0.0100
5		w_B	-0.0100	0.00	Functio n	
from T 4.96385 =3 -0.0230554	C	v_C	E-03 4.973485	E-03 0.19	0.21	E-2 INSTS
		w_C	-0.0230652	0.00	1.E-	3 -4.96385
	E	v_E	E-03 -4.973567	E-03 0.2	0.21	E-2 -0.0230554
		w_E	-0.0230653	0.043	1.E-	3 8.07655
	F	v_F	E-03 8.0767953	E-03 0.003	-0.0100 0	
		w_F	-0.01000	0.00	Modeliz ation	

4 B Characteristic

4.1 of the modelization L”

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

conditions: DDL_
```
       IMPO=_F ( GROUP_NO=' Npoutre”, DX= 0.0  ,  DRY=  0.0,  DRZ=  0.)  _F
(NOEUD
                  = (“A”,” 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 command 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: Characteristics A , B , C , D , E , F

4.2 of the mesh Many

nodes: 45 Number of meshes

and types: 44 SEG2 Quantities

4.3 tested and Case results

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

	B	v_B	E-6 – 5.6612	E-6 0.02	1.E-	3 3 Thermal expansion
		w_B				
– 1.305	C	v_C	E-4 – 1.3051	E-4 0.01	5.248	
	D	w_D	E-4 5.2484	E-4 0.01	– 3.111	
	B	v_B	E-3 – 3.1145	E-3 0.11	5.E-	3 4 –
4.552		w_B	E-3 – 4.5521	E-3 0.00	Gravity	
1.180	C	v_C	E-3 1.1409	E-3 – 3.31	5.E-	2 – 8.850
	D	w_D	E-3 – 8.8148	E-3 – 0.40	5.E-	3 Remarks

4.4 The modelization

of the elbow by right elements requires a very fine mesh, for a sufficient accuracy (in particular for a distributed loading). Summary

5 of the results

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

the modelization, they B are very close also () except $< 4.0\,10^{-4}$ for the loading case to gravity (of variation 3% to the maximum) because of the dependence of the solution to the smoothness of discretization. This test

thus validates element POU_C_T .