SSNL114 - Heavy cable with thermal thermal expansion

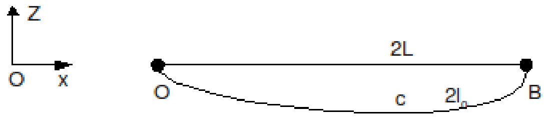
Abstract:
This test validates the computation of the cables subjected to gravity, with or without thermal thermal expansion.

- Static analysis
- Behavior elastic
- Large displacements
- 2 modelizations: `CABLE` and `POU_D_T_GD`

1 Problem of reference

1.1 Geometry

a cable length $2l_0$ at rest, in the direction x, is subjected its inertia loading (gravity in direction $-Z$). It is embedded at the ends O and B, themselves distant of $2\mathrm{L}$.



Initially, $2l_0 = 2L = 325\mathrm{m}$

the area of the section of the cable is worth: $2.2783\mathrm{E}-04\, m^2$

1.2 Material properties

$E = 5.70\, E+10\, Pa$
$\nu = 0.3$ (modelization B only)
$ALPHA : 2.3\, E-5\, K^{-1}$
$RHO : 2.844230\mathrm{E}+03\, kg/m^3$

1.3 Boundary conditions and loadings

Fixed support in O and B
Gravity: $(9.81, 0.0, 0.0, -1.0)$
The temperature in the cable varies according to time, the reference temperature is $0.\,°C$.

- Time: 0. Temperature $T = 0.\,°C$
- Time: 1.Température $T = 39.26\,°C$

One thus treats:

- at time 0, a cable subjected to its only inertia loading
- at time 1, a heavy cable subjected to a thermal thermal expansion.

2 Reference solution

2.1 Method of calculating used for the analytical reference solution

Solution:
For an extensible cable (elastic), subjected to its inertia loading, displacement is worth:

$$x(s)=a\,Argsh\left(\frac{s}{a}\right)+\frac{\rho g}{E}l_0$$

$$z(x)=a\sqrt{1+\frac{s^2}{a^2}}+\frac{\rho g}{E}\frac{s^2}{2}-a\sqrt{1+\frac{l_0^2}{a^2}}-\frac{\rho g}{E}\frac{l_0^2}{2}$$

a solution of the equation $L=a\,Argsh\left(\frac{l_0}{a}\right)+\frac{\rho g}{E}a\,l_0=f(a)$

With s curvilinear abscisse $s\in[-l_o,l_o]$. One is interested here in the deflection in the center (not C):

$$z(C)=a-a\sqrt{1+\frac{l_0^2}{a^2}}-\frac{\rho g}{E}\frac{l_0^2}{2}$$

a solution of the equation $L=a\,Argsh\left(\frac{l_0}{a}\right)+\frac{\rho g}{E}a\,l_0=f(a)$

the only difficulty in the computation of this solution is the resolution of the equation $L=f(a)$. This resolution was made numerically (FORTRAN program using the routine of search for zero of Aster `ZEROFO`).

Note:

In the case of thermal thermal expansion, the solution is the same one as previously, by considering that the initial length $2l_0$ is equal to its increased initial $2L$ length of linear thermal expansion: $l_0=L(1+\alpha T)$

2.2 Results of reference

Displacement in Z to the point C

2.3 Uncertainty on the solution

semi Solution - analytical: the numerical resolution of the equation $L=f(a)$ gives a value to 10^{-3} near.

2.4 Bibliographical references

[1 C.CONEIM “On the approximation of the equations of the static of the overhead cables in the presence of electromagnetic fields of forces”. Thesis and note HI/3640-02 (February 1981)

3 Modelization A

3.1 Characteristic of the modelization

elements CABLE

3.2 Characteristics of the mesh

27 elements CABLE

3.3 Quantities tested and results

$DZ(C)$ (m)	Urgent	Point	Identification	Reference	$\%$ difference
	0.	C	DZ	– 6.352	0.025
	1.	C	DZ	– 8.195	0.012

4 Modelization B

4.1 Characteristic of the modelization

elements POU_D_T_GD
In order not to disturb the solution, the values of inertias of bending are selected arbitrarily small: for a section of area $2.2783\text{E}-4$, one installation $IY=IZ=1.0\text{E}-4$
Announces however that values cannot be taken smaller without causing error in the resolution.

4.2 Characteristics of the mesh

27 elements POU_D_T_GD

4.3 Quantities tested and results

$DZ(C)$ (m)	Urgent	Point	Identification	Reference	% difference
	0.	C	DZ	– 6.352	0.4
	1.	C	DZ	– 8.195	0.2

5 Summary of the results

the results show that one can obtain the solution of the problem of the heavy cable with a good accuracy for the cable elements (0.02%), and an accuracy acceptable for elements POU_D_T_GD (0.4%).

Indeed, this mechanical problem is difficult for the algorithm of resolution, because the solution can be obtained only with the assumption of large displacements. Convergence can be obtained only with the geometrical stiffness matrix.