SSNL114 - Heavy cable with thermal dilation

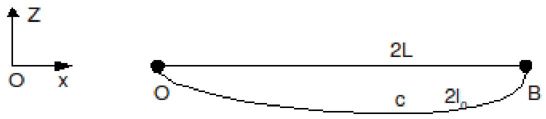
Summary:
This test validates the calculation of the cables subjected to gravity, with or without thermal dilation.

- Static analysis
- Elastic behavior
- Great displacements
- 2 modelings: `CABLE` and `POU_D_T_GD`

1 Problem of reference

1.1 Geometry

A cable length $2l_0$ at rest, in the direction x, its actual weight is subjected (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 surface of the section of the cable is worth: $2.2783\mathrm{E}-04\,m^2$

1.2 Material properties

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

1.3 Boundary conditions and loadings

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

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

One thus treats:

- at moment 0, a cable subjected to its only actual weight
- at moment 1, a heavy cable subjected to a thermal dilation.

2 Reference solution

2.1 Method of calculating used for the reference solution

Analytical solution:
For an extensible cable (elastic), subjected to its actual weight, 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 X-coordinate, $s\in[-l_o,l_o]$. One is interested here in the arrow 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 calculation of this solution is the resolution of the equation $L=f(a)$. This resolution was numerically made (FORTRAN program using the routine of search for zero of Aster `ZEROFO`).

Note:

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

2.2 Results of reference

Displacement in Z at the point C

2.3 Uncertainty on the solution

Semi solution - analytical: the digital resolution of the equation $L=f(a)$ give a value to 10^{-3} near.

2.4 Bibliographical references

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

3 Modeling A

3.1 Characteristics of modeling

elements CABLE

3.2 Characteristics of the grid

27 elements CABLE

3.3 Sizes tested and results

$DZ(C)$ (m)	Moment	Not	Identification	Reference	% difference
	0.	C	DZ	– 6,352	0,025
	1.	C	DZ	– 8,195	0,012

4 Modeling B

4.1 Characteristics of modeling

elements POU_D_T_GD
In order not to disturb the solution, the values of inertias of inflection are selected arbitrarily small: for a section of surface $2.2783\mathrm{E}-4$, one poses $IY=IZ=1.0\mathrm{E}-4$
Let us announce however that values cannot be taken smaller without causing error in the resolution.

4.2 Characteristics of the grid

27 elements POU_D_T_GD

4.3 Sizes tested and results

$DZ(C)$ (m)	Moment	Not	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 precision for the elements of cable (0.02%), and a precision acceptable for the 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 great displacements. Convergence can be obtained only with the geometrical matrix of rigidity.