SSNV229 - Validation of formulas ETCC in DEFI_CABLE_BP

Summary:

The goal of this CAS-test is to validate formulas ETCC established in the operator DEFI_CABLE_BP, which calculates the profiles of tension in the cables of prestressed of a structure of concrete. The losses taken into account in Code_Aster are the losses of tension by friction between the cables and the concrete, by retreat with anchorings, and relieving of steel, material constituting the cables.

The structure considered is a cylinder, containing in its thickness ten cables of prestressing. The cables describe each one a circle in a horizontal plane, and traverse the structure over its length. All the cables are anchored on the same line.

The got results are validated by comparison with those theoretically expected. Two modelings are proposed. Modeling A makes it possible to test the direct taking into account of the relieving of steels (approximate method). Modeling B makes it possible to more finely model the relieving of steels by carrying out a short-term calculation and a long-term calculation which could be combined with the modeling of the withdrawal and creep in the concrete.

1 Problem of reference

1.1 Geometry

It is about a concrete cylinder height is $H=10\,m$ and of average radius $R=20.5\,m$.

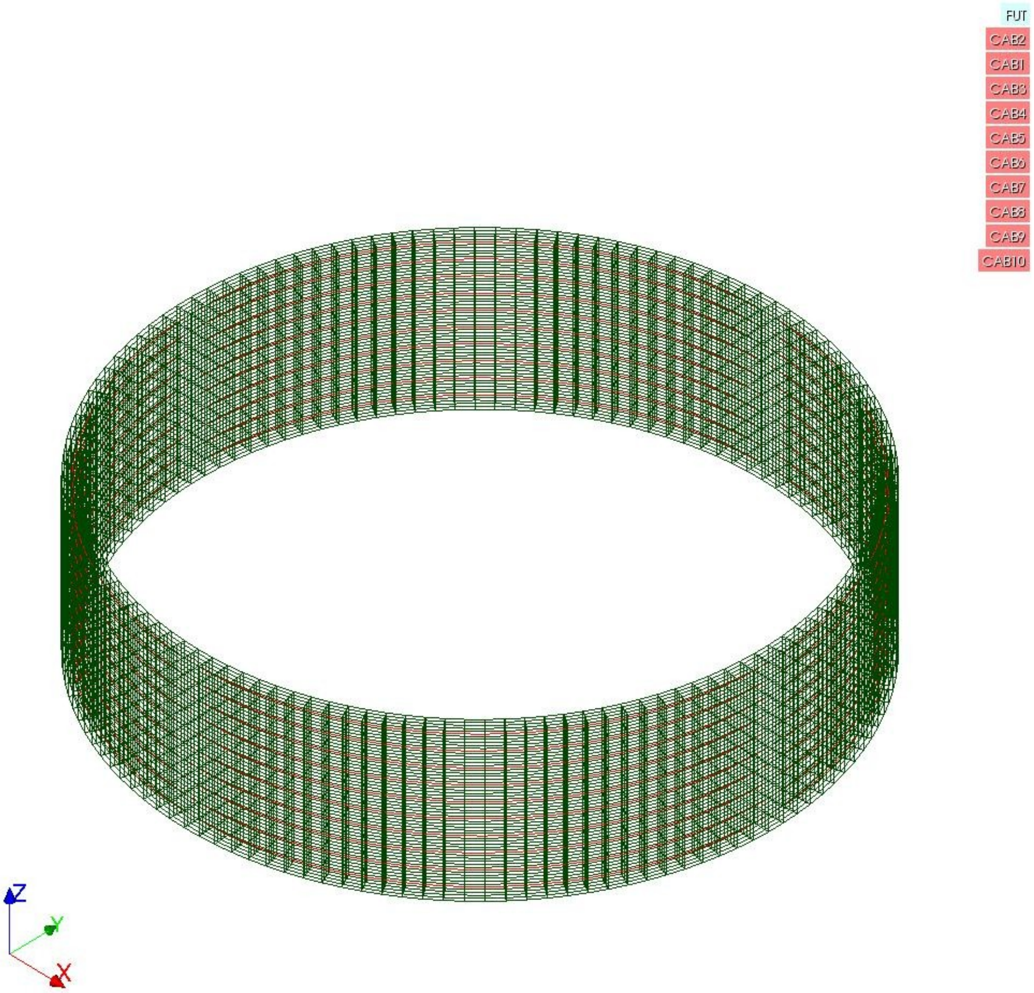

Figure 1.1-a: studied model

The thickness of the veil is worth $e=1\,m$.

The cables describe each one a circle in a horizontal plane, and thus traverse the structure over its length. All the cables are anchored on the same line. The 10 cables are spaced of $1\,m$ enter $z=-4.5\,m$ and $z=4.5\,m$.

The surface of the cross-section of each cable is worth $S_a=7.923\,10^{-3}\,m^2$.

1.2 Properties of materials

1.2.1 Material concrete constituting the veil

Elastic properties:

Young modulus $E_b = 3.10^{10}\, Pa$

Poisson's ratio $\nu_b = 0{,}2$

1.2.2 Material steel constituting the cables

Elastic properties:

Young modulus $E_a = 1{,}915.10^{11}\, Pa$

Poisson's ratio $\nu_a = 0{,}3$

Parameters characteristic for estimate of the losses of tension:

Elastic ultimate stress of steel $f_{prg} = 1{,}814.10^{9}\, Pa$

Coefficient of friction $\mu = 0{,}17$

Loss ratio on line $k = \frac{0{,}0015}{0{,}17}\, m^{-1}$

Relieving of steel at 1000 hours $\rho_{1000} = 2{,}5\,\%$

1.3 Loading

One applies at the two ends of each cable a normal effort of traction. The value of the pressure applied in steel is $\sigma_0 = 0{,}8\, F_{prg} = 1487{,}48\, MPa$ that is to say a tension $F_0 = 11{,}785.10^{6}\, N$.

To evaluate the losses of tension in the vicinity of anchorings, one takes account of a retreat with anchorings $\Delta = 8.10^{-3}\, m$.

The characteristics are evaluated after 65 years, that is to say $t = 569790\, h$ who corresponds to the parameter NBH_RELAX.

2 Reference solution

2.1 Normal effort in the cables

The reference solution was obtained by a worksheet under Excel carried out by company GDS.

Two modelings correspond to two ways of calculating of the loss of prestressing due to the relieving of steels.

- In modeling A, the losses by relieving are considered by neglecting the elastic losses (direct calculation with DEFI_CABLE_BP) that is to say:

  $$F_i(s)=F_0\exp^{-\mu(\theta+ks)}-\text{recul d'ancrage}$$

  and finally:

  $$F(s)=F_i(s)-0{,}66\,\rho_{1000}.\exp^{9,1F_i(s)/F_{prg}}.\left(\frac{t}{1000}\right)^{0,75(1-F_i(s))/F_{prg}}.10^{-5}F_i(s)$$

- In modeling B, the losses by relieving of steels are calculated starting from the tension taking of account the elastic losses obtained by a preceding calculation, where the cables were put in tension in 2 groups, that is to say:

for group 1 (odd cables):

$$F_i^1(s)=F_0\exp^{-\mu(\theta+ks)}-\text{recul d'ancrage}-\frac{A_pE_p\Delta\sigma_c(x)}{E}$$

for group 2 (even cables):

$$F_i^2(s)=F_0\exp^{-\mu(\theta+ks)}-\text{recul d'ancrage}$$

and $$F(s)=F_i^{1,2}(s)-0{,}66\,\rho_{1000}.\exp^{9,1F_i^{1,2}(s)/F_{prg}}.\left(\frac{t}{1000}\right)^{0,75(1-F_i^{1,2}(s))/F_{prg}}.10^{-5}F_i^{1,2}(s)$$

The value of reference actually has was obtained by considering that one had the same elastic losses on all the cables being worth $\Delta F_{el}(s)=\frac{A_pE_p\Delta\sigma_c(x)}{2E}$.

3 Modeling A

3.1 Characteristics of modelings

The concrete wall is represented by elements 3D supported in both cases by hexahedral meshs with 8 nodes: one counts 10 meshs on a vertical generator, 4 meshs in the thickness and 126 on the circumference.

To separately validate the taking into account of the losses by friction and retreat of anchoring, one considers the losses by relieving only on the even cables.

3.2 Sizes tested and results

The component tested is the tension in the cables NR.

Curvilinear value X-coordinate (in meters)	Cable concerned	Type of reference	Value of reference [N]	Tolerance ($\%$)
0.	'CAB1'	'ANALYTICAL'	$9{,}537.10^{6}$	0,50%
9,2	'CAB1'	'ANALYTICAL'	$10{,}436.10^{6}$	0,50%
64,4	'CAB1'	'ANALYTICAL'	$6{,}273.10^{6}$	0,50%
0.	'CAB2'	'ANALYTICAL'	$9{,}286.10^{6}$	0,50%
9,2	'CAB2'	'ANALYTICAL'	$10{,}079.10^{6}$	0,50%
64,4	'CAB2'	'ANALYTICAL'	$6{,}210.10^{6}$	0,50%

3.3 Remarks

The variations are very weak, knowing that the discretization of the cable is not completely identical. The most important variation is at the level of the anchoring and the estimate of the losses by retreat of anchoring.

4 Modeling B

4.1 Characteristics of modeling and grid

The grid is identical to modeling A. On the other hand, the calculation of the tension is carried out in 2 stages.

- In the first the calculation of the tension is carried out by taking only into account the losses by friction and by moves back of anchoring. The setting in tension is then carried out using `CALC_PRECONT` , in two stages allowing to recover the elastic losses: the setting in tension of the odd cables initially then the setting in tension of the even cables.
- In the second phase, the calculation of the tension of the cables is carried out by modelling the relieving of steels.

4.2 Sizes tested and results

The component tested is the tension in the cables `NR`.

Curvilinear value X-coordinate (in meters)	Cable concerned	Type of reference	Value of reference [N]	Tolerance ($\%$)
0.	'CAB9'	'ANALYTICAL'	$9,289.10^6$	0,50%
9,2	'CAB9'	'ANALYTICAL'	$10,085.10^6$	0,50%
64,4	'CAB9'	'ANALYTICAL'	$6,210.10^6$	0,50%
0.	'CAB10'	'ANALYTICAL'	$9,289.10^6$	0,50%
9,2	'CAB10'	'ANALYTICAL'	$10,085.10^6$	0,50%
64,4	'CAB10'	'ANALYTICAL'	$6,210.10^6$	0,50%

5 Summary of the results

The got results are validated by comparison with those theoretically expected with a good precision.

The particular features tested are the following ones:

- operator `DEFI_MATERIAU` [U4.23.01]: definition of the parameters characteristic of the materials steel and concrete allowing calculation of the tension along the cables of prestressing, the rules of the ETCC;
- operator `DEFI_CABLE_BP` [U4.23.06]: calculation of the tension along the cables;