SSNV229 - Validation of formulas ETCC in

Summarized

DEFI_CABLE_BP:

The goal of this benchmark is to validate formulas ETCC established in the operator DEFI_CABLE_BP, who 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 the anchorages, and relaxation of steel, material constituting the cables.

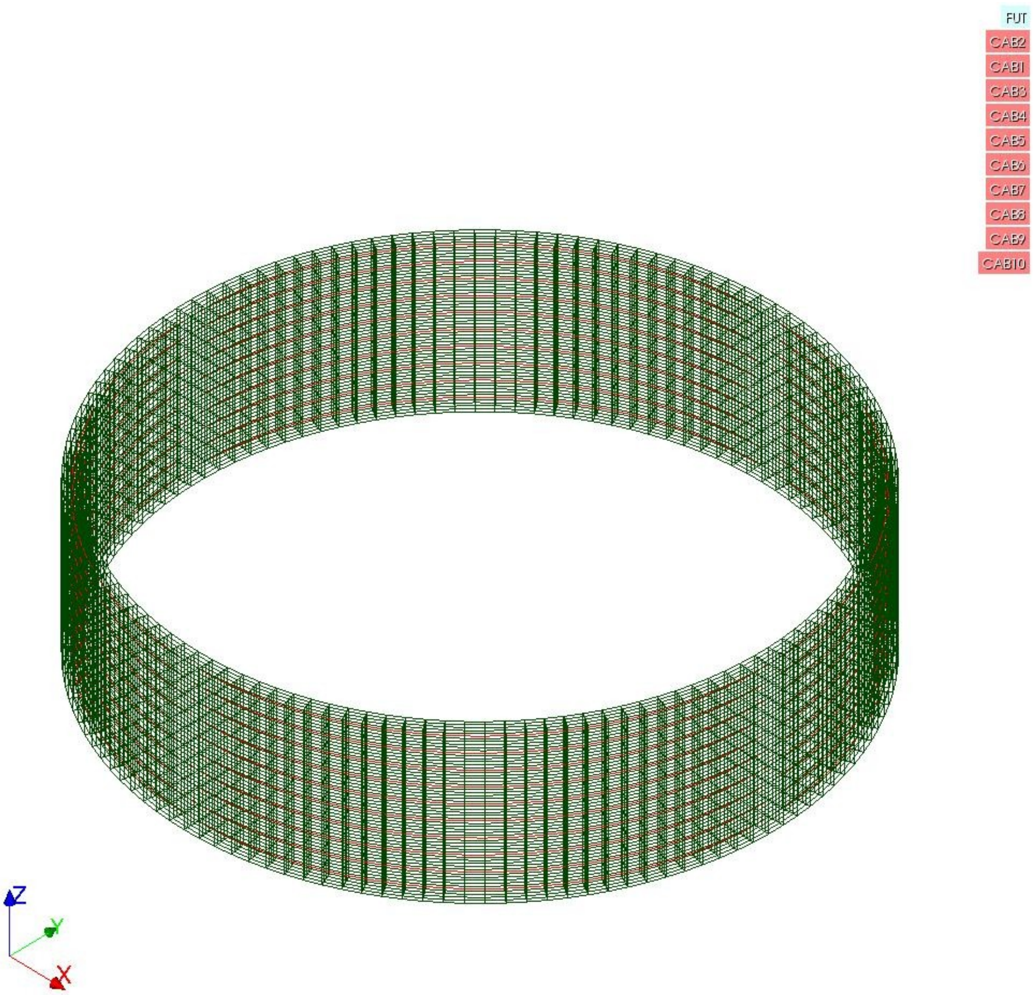
The structure considered is a cylinder, containing in its thickness ten cables of prestressing. The cables describe each one a circle in a horizontal plane, and traverse structure over its length. All the cables are anchored on the same one line.

The got results are validated by comparison with those theoretically expected. Two modelizations are proposed. The modelization A allows to test the direct taking into account of the relaxation of steels (approximate method). The modelization B allows to more finely model the relaxation of steels by carrying out a short-term computation and a long-term computation which could be combined with the modelization of the shrinkage and creep in the concrete.

1 Problem of reference

1.1 Geometry

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



Appears 1.1-a: model studied

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

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

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

1.2 Properties of the materials

1.2.1 Concrete material 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 elastic

cables 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:

Stress yield stress of steel	$f_{prg} = 1{,}814.10^{9}\,Pa$
Coefficient of kinetic friction	$\mu = 0{,}17$
formulates loss Ratio in	$k = \frac{0{,}0015}{0{,}17}\,m^{-1}$
Relaxation of steel at 1000 hours	$\rho_{1000} = 2{,}5\,\%$

1.3 Loading

One applies at the two ends of each cable a normal force of tension. The value of the pressure applied in steel is $\sigma_0 = 0{,}8\,F_{prg} = 1487{,}48\,MPa$ is a tension $F_0 = 11{,}785.10^{6}\,N$.
To evaluate the losses of tension in the vicinity of the anchorages, one takes account of a retreat with the anchorages $\Delta = 8.10^{-3}\,m$.

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

2 Reference solution

2.1 normal Force in the cables

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

The two modelizations correspond to two ways of calculating of the loss of prestressing due to the relaxation of steels.

- In the modelization A, the losses by relaxation are considered by neglecting the elastic losses (direct computation with DEFI_CABLE_BP) that is to say:

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

and finally:

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

- In the modelization B, the losses by relaxation of steels are calculated from the tension taking into account the elastic losses obtained by a preceding computation, where the cables were put in tension in 2 groups, that is to say:

for group 1 (odd cables):

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

for group 2 (even cables):

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

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

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

3 Modelization A

3.1 Characteristic of the modelizations

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

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

3.2 Quantities tested and results

the component tested is the tension in the cables N.

Value curvilinear abscisse (in meters)	Cables concerned	Type of reference	Value of reference [N]	Tolerance (%)
0.	"CAB1"	"ANALYTIQUE"	9,537.106	0.50%
9.2	"CAB1"	"ANALYTIQUE"	10,436.106	0.50%
64.4	"CAB1"	"ANALYTIQUE"	6,273.106	0.50%
0.	"CAB2"	"ANALYTIQUE"	9,286.106	0.50%
9.2	"CAB2"	"ANALYTIQUE"	10,079.106	0.50%
64.4	"CAB2"	"ANALYTIQUE"	6,210.106	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 anchorage and the estimate of the losses by retreat of anchorage.

4 Modelization B

4.1 Characteristic of the modelization and mesh

The mesh is identical to modelization A. On the other hand, the computation of the tension is carried out in 2 stages.

- In the first the computation of the tension is carried out by taking only into account the losses by friction and by moves back of anchorage. The setting in tension is then carried out using `CALC_PRECONT` , in two stages making it possible 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 computation of the tension of the cables is carried out by modelling the relaxation of steels.

4.2 Quantities tested and results

the component tested is the tension in the cables `N`.

Value curvilinear abscisse (in meters)	Cables concerned	Type of reference	Value of reference [N]	Tolerance ($\%$)
0.	"CAB9"	"ANALYTIQUE"	9,289.106	0.50%
9.2	"CAB9"	"ANALYTIQUE"	10,085.106	0.50%
64.4	"CAB9"	"ANALYTIQUE"	6,210.106	0.50%
0.	"CAB10"	"ANALYTIQUE"	9,289.106	0.50%
9.2	"CAB10"	"ANALYTIQUE"	10,085.106	0.50%
64.4	"CAB10"	"ANALYTIQUE"	6,210.106	0.50%

5 Summary of the results

the got results are validated by comparison with those theoretically expected with a good accuracy.

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 computation of the tension along the cables of prestressing, the rules of the ETCC;
- operator `DEFI_CABLE_BP` [U4.23.06]: computation of the tension along the cables;