PLEXU10 - Validation of the cables slipping and rubbing in CALC_EUROPLEXUS

Summary:

Mechanisms making it possible to model slipping and rubbing cables were added in EUROPLEXUS.

These series of tests validate the call of CALC_EUROPLEXUS in these features with prestressing calculated in Code_Aster or not, but takes part also directly in their validations in EUROPLEXUS.

Slipping cables:
The modeling of the slipping cables is done only by one connection (*LCAB GLIS*). This connection, inspired of the loading RELA_CINE_BP of Code_Aster, calculates the relations kinematics between concrete and cable by leaving free the movement of each node of cable in the tangent direction with the trajectory of the cable. In order to take into account the great deformations and the great slips, this connection is reactualized with each step of time.

Rubbing cables:
The modeling of the rubbing cables is made by using the same connection as for the slipping cables. Specific discrete elements are used to model friction. Connections must also be made on the nodes of the noncommon discrete elements with elements of cables. This connection is activated by syntax *LCAB FROT*.

Modeling a: Validation of the call to connection EPX *LCAB GLIS* (reproduction of the test bm_str_lcab_glis).

Modeling b: Validation of the good taking into account of an initial state of prestressed with the connection *LCAB GLIS* .

Modeling C: Setting in tension of a cable slipping into EPX (Code_Aster reference).

Modeling D : Validation of the call to connection EPX *LCAB FROT* , (reproduction of the test bm_str_lcab_frot_amor). This test takes part in the validation of LCAB FROT in EPX, it provides a value of reference for a setting in tension of a cable rubbing with passing of anchoring.

Modeling E : Reproduction of the test bm_str_lcab_frot

Modeling F : Validation of the Code_Aster/EPX chaining with rubbing cables .

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1 Description

1.1 Geometry, grid and model

The model of study is a portion of half-cylinder height $H=2m$ of ray $R=10m$ and thickness $ep=1m$. This half-cylinder is prolonged at its end located in $x>0$ by a rectilinear part of the same height and of $3m$ of length. A cable crosses the concrete while following its geometry to a distance $ex=0,4m$ average layer on the external side.

The concrete is modelled in hull (element `Q4GG`). It consists of 275 meshs `QUAD4` , 5 meshs in its height and 55 over the length (including 50 on the cylindrical part and 5 on the rectilinear part).

The cable is modelled in elements `BAR` , it consists of 55 meshs `SEG2` .

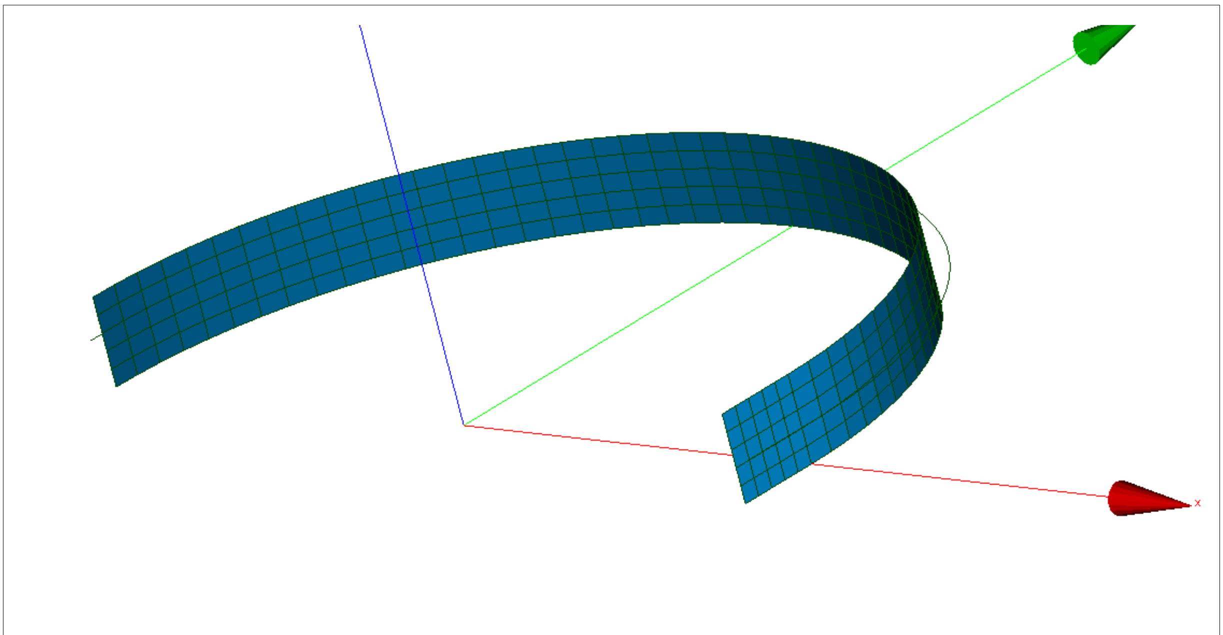

Illustration 1: Grid

For modelings D, E and F, elements `DIS_T` resting on meshs `SEG2` to the confused nodes (the first node being a node of cable) are added to the grid (using the functionality `CREA_SEG2` of `CREA_MAILLAGE`) and with the model.

1.2 Properties of materials

The properties of the concrete for the cylinder and steel for the cable are given in the following table:

Material	Concrete	Steel	
Young modulus	$3\times10^{10}Pa$	$2\times10^{11}Pa$	
Poisson's ratio	0.0	0.0	
Density	$2500\,kg/m^3$	Modeling With, B and C $500\,kg/m^3$	Modeling D, E and F $7800\,kg/m^3$

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2 Modeling A

In this modeling, one seeks to validate the good use of the connection *LCAB GLIS* EPX in `CALC_EUROPLEXUS`. This connection is activated starting from the loading `RELA_CINE_BP` of`AFFE_CHAR_MECA` while giving to the keyword `TYPE_EPX` the value " `GLIS` ".

2.1 Boundary conditions and loadings

Nodes in red on the illustration 2 are embedded.

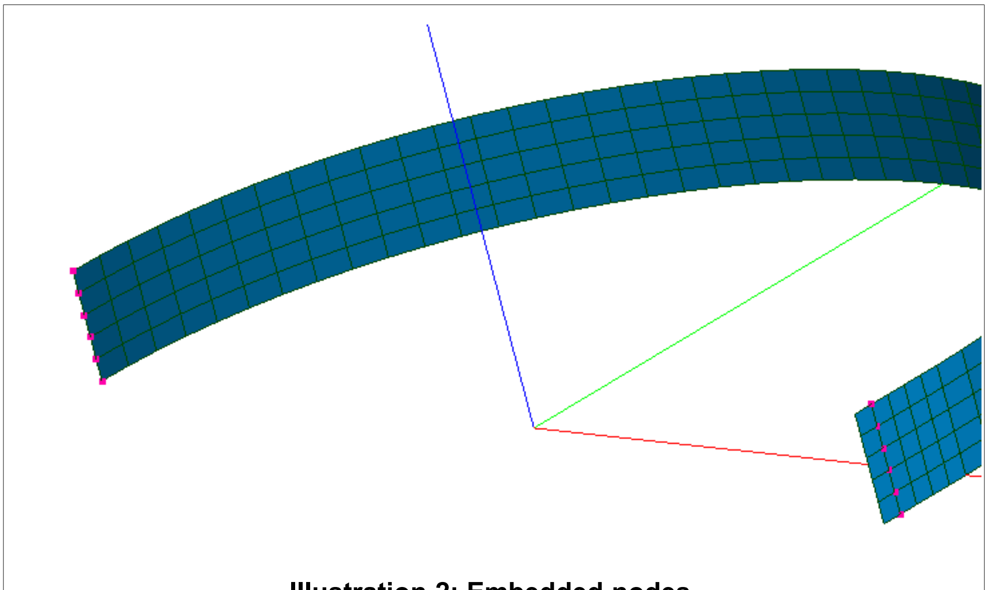

Illustration 2: Embedded nodes

Displacement $DY=-3\mathrm{m}$ as well as blockings of the ddls of rotations are imposed on the nodes in red on the illustration 3 .

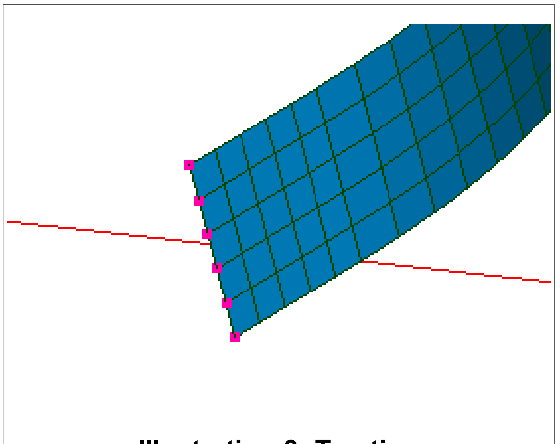

Illustration 3: Traction

This loading is imposed with the following multiplying function:

Time	Coefficient
0.	0.0
0,002	1.0

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1.0	1.0

2.2 Details

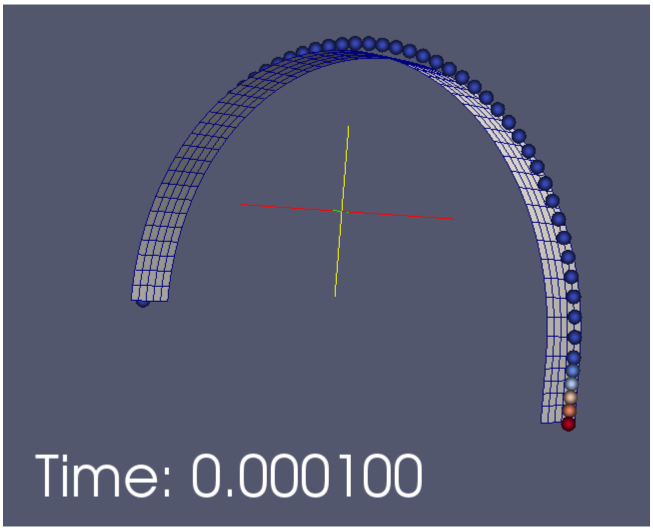
Without the presence of the connections between the cable and the concrete the loading would have effect only on the 5 meshs at the end where traction is applied. The connection *LCAB GLIS* impose a total kinematic relation on the two nodes at the ends of the cable (or nodes of anchoring) and a partial kinematic relation with the other nodes (not of connection in the direction of the cable).

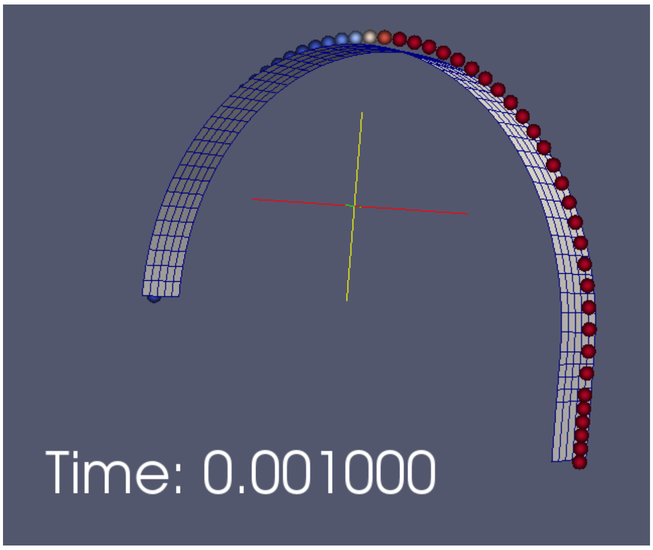
The imposed loading will thus involve the node of anchoring with the concrete nodes, which will draw on all the cable.

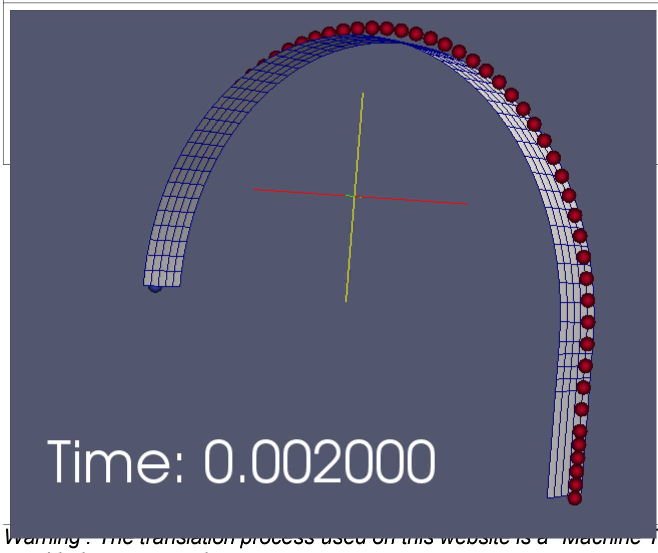
The nodes of cable move then along the trajectory. For this test and its equivalent in EPX the validation is visual. One used the module ParaVIS de SalomeMeca to in the course of time visualize displacements of the nodes of cables.

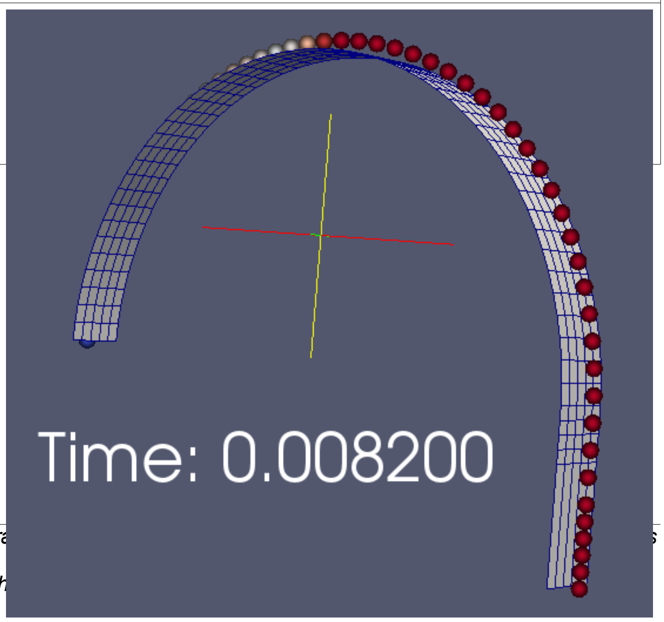
Once this visualization carried out, of the tests of nonregression were added to test EPX. In order to validate the call of `CALC_EUROPLEXUS` with connection EPX *LCAB GLIS,* one tests the same values as EPX.

A video would be more speaking, one however shows the deformation of this calculation at several moments.









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2.3 Sizes tested and results

These tests have a reference `SOURCE_EXTERNE` given by corresponding test EPX.

Node	Component	Moment (S)	Value of reference (m)	Tolerance
NY10	*DX*	0,002	1.58933	2.E−6
NY10	*DY*	0,002	−0.125243	2.E−6
NY10	*DX*	0,006	2.17663	2.E−6
NY10	*DY*	0,006	−0.277227	2.E−6
NY10	*DX*	0.01	2.52102	2.E−6
NY10	*DY*	0.01	−0.394618	2.E−6

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3 Modeling B

This modeling validates the use of an initial state of prestressed with connection EPX *LCAB GLIS*.

3.1 Boundary conditions and loadings

The 6 nodes at each end of the concrete are embedded.

Moreover one assigns to the model a loading of the prestressed type calculated from DEFI_CABLE_BP and CALC_PRECONT. The tension imposed on the cable is defined by the keyword TENSION_INIT of DEFI_CABLE_BP, its value is put at $2.E5\,N$. This loading is sent to EPX in the form of an initial state.

3.2 Details

One applies in EPX prestressing without additional loading. During the calculation of this state prestressed by CALC_PRECONT , the relations kinematics between the cable and the concrete were total (i.e. in the three directions of space). For this test, while arriving in EPX, one will have sliding joints.

In spite of that one tests nevertheless that the system is with balance while arriving of EPX. Indeed, profile of constraint calculated in DEFI_CABLE_BP is made with coefficients of worthless frictions. The constraint is thus equal on all the meshs. Once in EPX, although the connections are slackened in each node in the tangent direction with the cable, the nodes do not move because of this profile of uniform constraint.

To test this balance, one carries out many steps of time and one checks on some values that nothing evolved.

Rq: it was checked that by calculating a profile of tension with friction the cable moved along its trajectory in EPX.

3.3 Sizes tested and results

These tests have a reference ANALYTICAL data the state of the system at exit of CALC_PRECONT.

Node	Component	Moment (S)	Value of reference (m)	Tolerance
NY10	*DX*	0.01	−2.40357805409E−06	3.E−5
NY10	*DY*	0.01	−6.40552798575E-05	1.E-6

Mesh	PG	Component	Moment (S)	Value of reference (m)	Tolerance
MY10	1	*NYY*	0.01	−100399.049696	1.E-6
MCAY10	1	*N*	0.01	200000.163668	1.2E-6

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4 Modeling C

This provided modeling a reference for the test EPX bm_str_lcab_glis_amor which validates the effect of the cable slipping on the concrete by reproducing a setting in tension into EPX. The Code_Aster reference is calculated with `DEFI_CABLE_BP` and `CALC_PRECONT`.

Test EPX bm_str_lcab_glis_amor uses the damping of EPX.

It uses at the same time `LIRE_EUROPLEXUS` without passing by `CALC_EUROPLEXUS` to recover the result of test EPX contained in a file MED (given in unit 19) and reproduced calculation with `CALC_EUROPLEXUS`.

4.1 Boundary conditions and loadings

Code_Aster:

Same boundary conditions as modeling B. the loading of prestressing differs only on the value from the initial tension given by `TENSION_INIT`. It is equal here to $2.37182E+08$.

The value of this tension is obtained starting from the component DY node `ANCR2` on field FLIA (bonding strengths) of EPX at the final moment of calculation. It is the force induced by the imposed displacement applied to the concrete.

EPX:

Same boundary conditions and loading that modeling A.

4.2 Details

As already known as, in calculation EPX one uses the features of damping to simulate a quasi-static calculation and thus to obtain a solution stabilized in a reasonable time.
One stops calculation with $0.2s$ while being ensured that nothing any more evolves.

4.3 Sizes tested and results

These tests have a reference `AUTRE_ASTER` given by the result resulting from `CALC_PRECONT`.

Mesh	PG	Component	Moment (S)	Value of reference (m)	Tolerance
$MY10$	1	NYY	0.2	-119202846.463	4.E-3
$MCAY10$	1	N	0.2	237528990.0	2.E-3

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5 Modeling D

This provided modeling a reference for the test EPX bm_str_lcab_frot_amor which reproduces the setting in tension of a rubbing cable. The values of reference are the profiles of tension calculated with DEFI_CABLE_BP.

Test EPX bm_str_lcab_frot_amor uses the damping of EPX.

It uses at the same time LIRE_EUROPLEXUS without passing by CALC_EUROPLEXUS to recover the result of test EPX contained in a file MED (given in unit 19) and reproduced calculation with CALC_EUROPLEXUS.

5.1 Material of friction

One assigns to the cable for Code_Aster and discrete of friction for EPX material BPEL_ACIER with the following parameters:

FROT_LINE	0.003
FROT_COURB	0.2

5.2 Boundary conditions and loadings

EPX:

Same boundary conditions and loading that modeling A. Seule the multiplying function changes to simulate the retreat of anchoring.

Time	Coefficient
0.	0.0
0,002	1.0
0.06	1.0
0.1	0.933333
1.0	1.0

The passage of the multiplying function with 0.933333 corresponds to a retreat of 0.2 m ANCR2.

Code_Aster:

Same boundary conditions as modeling B. the loading of prestressing differs only on the value from the initial tension given by TENSION_INIT. It is equal here to 315367000. The roll with DEFI_CABLE_BP is called twice, for the first time without retreat of anchoring and for the second time with a passing of anchoring of 0.116.

The value of the tension to be applied in Code_Aster was in the following way given. One recovered the results of calculation EPX. Field EPX of constraints of the cables was transformed into fields of effort. From this field at the points of Gauss (SIEF_ELGA) one calculated the field with the corresponding nodes (SIEF_NOEU). One then detected in the field of displacement at time 0.06s, the first node of cable starting from the node ANCR2 whose brought up to date coordinate Y did not exceed -2 Mr. Physiquement, it is the first node of cable which did not leave the concrete at the time of this phase of setting in tension. The value of the tension to be applied in Code_Aster is the value of the field of effort to the nodes with this node.

As opposed to what one could think, the retreat of anchoring to be applied in Code_Aster is not 0.2m but of 0.116m. Indeed the retreat of anchoring should not be calculated starting from node ANCR2 but

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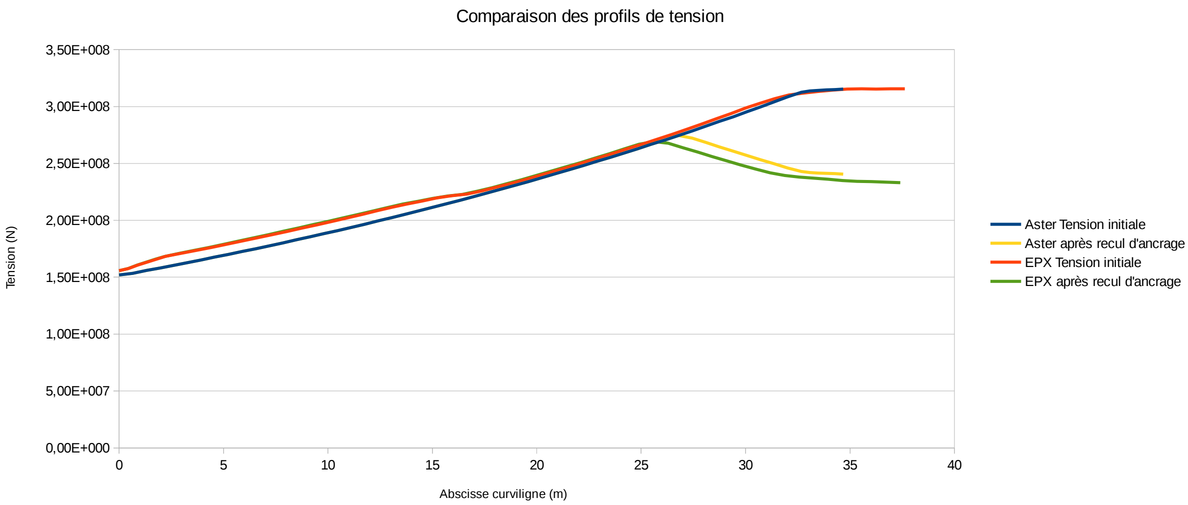
starting from the last node still included in the concrete following the initial phase. The value of 0.116m then is obtained.

5.3 Comparison of the profiles of tension



One gives here the analysis made in document EPX:

In the initial phase of setting in tension, one sees that the curves are superimposed almost perfectly for the curvilinear X-coordinates higher than approximately 20.0 m. By printing the value of the curves in each node calculated in EPX, one realized that some values in the middle of the cable were rather different from the others, whereas in the circular part the curve must be the same one in each point. This is probably the fact of very light inaccuracies in the grid on this level. Code_Aster does not see it because it uses a method of spline interpolating the trajectory of the cable overall whereas in EPX one locally interpolates simply the trajectory.

Concerning the retreat of anchoring, there are differences slightly larger but the curves are parallel on this part. The differences can come from a taking into account of friction on nodes normally left the concrete or interpretation the node reference for the determination the retreat anchoring to apply in Code_Aster.

5.4 Sizes tested and results

One test the maximum change of the profiles of tension of Code_Aster and EPX at the end of the phases of initial tension and retreat of anchoring.

Moment	Maximum change
0.06	0.0447086123078
0.12	0.0605346658829

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6 Modeling E

This test reproduces bench EPX bm_str_lcab_frot. It validates the use of the cables rubbing in EPX without damping.

6.1 Material of friction

One assigns to the cable for Code_Aster and discrete of friction for EPX material BPEL_ACIER with the following parameters:

FROT_LINE	0.018
FROT_COURB	0.38

These coefficients correspond to twice the coefficients of lawful frictions of type TICC (Strands Injected with Cement Grout).

6.2 Sizes tested and results

Node	Component	Moment (S)	Value of reference (m)	Tolerance
NY10	*DX*	0.11	2.27750E-01	1.E-3
NY10	*DX*	0.4	2.37959E-01	1.E-3

Mesh	PG	Component	Moment (S)	Value of reference (m)	Tolerance
MCAY10	1	*N*	0.11	40510650.0	1.E-3
MCAY10	1	*N*	0.4	38661900	1.E-3

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7 Modeling F

This modeling validates the use of an initial state of prestressed with connection EPX *LCAB FROT*. It corresponds to the tests “bm_str_lcab_frot_ini_med” and “bm_str_lcab_frot_ini_amor”.

7.1 Boundary conditions and loadings

The 6 nodes at each end of the concrete are embedded.

Moreover one assigns to the model a loading of the prestressed type calculated from DEFI_CABLE_BP and CALC_PRECONT. The tension imposed on the cable is defined in DEFI_CABLE_BP by the keyword TENSION_INIT and RECUL_ANCRAGE, of which the values are respectively of $2.\mathrm{E}7\,N$ and $0.01\,m$. This loading is sent to EPX in the form of an initial state.

7.2 Details

Two calculations are carried out. In both cases, O N applies in EPX prestressing without additional loading. In the first, keyword EQUI is put at ‘YES’ so that EPX balances the initial state given Code_Aster. It is checked whereas the system does not evolve. In the second, EQUI is put at ‘NOT’. A light damping is added to let the system balance all alone.

7.3 Sizes tested and results

Calculation 1:

These tests have a reference ANALYTICAL data the state of the system at exit of CALC_PRECONT.

Node	Component	Moment (S)	Value of reference (m)	Tolerance
NY10	*DX*	0.01	−1.46059E-04	1.E-3
NY10	*DY*	0.01	−3.61863E-03	1.E-3

Mesh	PG	Component	Moment (S)	Value of reference (m)	Tolerance
MCAY10	1	*N*	0.01	14051238.3598	1.E-3

Calculation 2:

These tests have a reference SOURCE_EXTERNE.

Node	Component	Moment (S)	Value of reference (m)	Tolerance
NY10	*DX*	0.2	1.36726E−04	1.E−3
NY10	*DY*	0.2	−3.69190E-03	1.E-3

Mesh	PG	Component	Moment (S)	Value of reference (m)	Tolerance
MCAY10	1	*N*	0.2	14278815.0	1.E-3

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8 Synthesis

Various modelings validate the following points well:

- the use of the connection *LCAB GLIS* EPX in `CALC_EUROPLEXUS` without prestressing;
- the use of the connection *LCAB GLIS* EPX in `CALC_EUROPLEXUS` with prestressing;
- the effect of the cables slipping on the concrete into EPX;
- the use of the connection *LCAB FROT* EPX in `CALC_EUROPLEXUS` without prestressing;
- the use of the connection *LCAB FROT* EPX in `CALC_EUROPLEXUS` with prestressing;
- the calculation of the force threshold of law BPEL of EPX.

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