SSNV164 - Put in tension of cables of prestressed in a beam 3D

Summarized

One considers a reinforced concrete beam of section square, composed of two 10 meters length sections, having respectively one and four square meters of section. The beam is vertical, the weakest section in bottom. It is embedded at its base, and contains 5 rectilinear cables of prestressing.
One tests here the phasage of the setting in prestressing, i.e. the setting in successive tension of the various cables.
The features particular to test are the following ones:

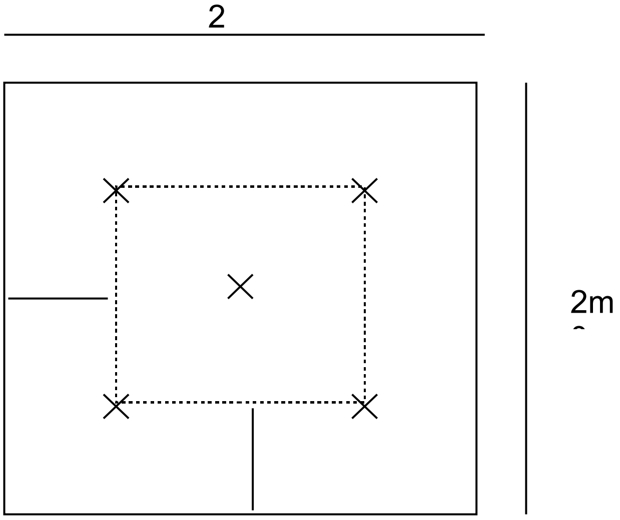
- operator `DEFI_CABLE_BP` : determination of the kinematic relations between the degrees of freedom of the nodes of a cable and the degrees of freedom of the nodes “close” to a concrete structure modelled by elements $3\mathrm{D}$ and computation of the tensions in a cable under the friction effect and of the retreat of anchorage,
- operator `AFFE_CHAR_MECA` associated to the key word `RELA_CINE_BP`,
- operator `CALC_PRECONT` : setting in tension of the cables of prestressed with the classical method `of` NEWTON or method `IMPLEX`.

The got results are validated by comparison with the computer code CASTEM 2000.
The modelization B allows more specifically to validate the use of key word `CONE` in `DEFI_CABLE_BP.`

1 Problem of reference

1.1 Geometry

One considers a reinforced concrete beam of section square, made up of two 10 meters length sections, having respectively one and four square meters of section. The beam is vertical, the weakest section in bottom. It is embedded at its base, and contains 5 rectilinear cables of prestressing.
The five cables which cross all the length of the beam are located as on the plane below:



1.1-a: Positioning of the cables in the beam

the section of each cable is of $25\,cm^2$.

1.2 Properties of the materials

Concrete material constituting beam:

Young modulus:	$E_b = 4.\,10^5\,MPa$
Poisson's ratio:	$\nu = 0{,}2$
density:	$\rho = 2500\,kg/m^3$
limit in tension	$\sigma_Y = 3\text{MPa}$
hardening modulus	$E_{bT} = -10000\,MPa$

Material steel constituting the cable:

Young modulus:	$E_c = 1{,}93\,10^5\,MPa$
Poisson's ratio:	$\nu = 0{,}3$
density:	$\rho = 7850\,kg/m^3$
limit in tension	$\sigma_Y = 19400\text{MPa}$
hardening modulus	$E_{bT} = 10\text{E-3}\,MPa$

Characteristic concerning the setting in tension of the cables:

- retreat of anchorage: $1\,mm$
- linear coefficient of kinetic friction: $0{,}0015\,m^{-1}$
- force tension at the end of a cable: $3{,}75\,10^6\,N$
- age of old dismantling 150

- days of setting in tension of the first cable: 300 Boundary conditions

1.3 days and loadings

the base of the beam is blocked in the direction Z. The two translatory movements compared to OX and OY are blocked as well as the rotation movement around OZ.
The sequence of loading is the following one:

- at 300 days, put in tension of 2 cables (1 and 2) by their lower end,
- at 450 days, put in tension of 2 additional cables (3 and 4) always by their lower end,
- at 600 days, put in tension of the last cable (5) by its two ends.

The beam is obviously subjected to gravity.

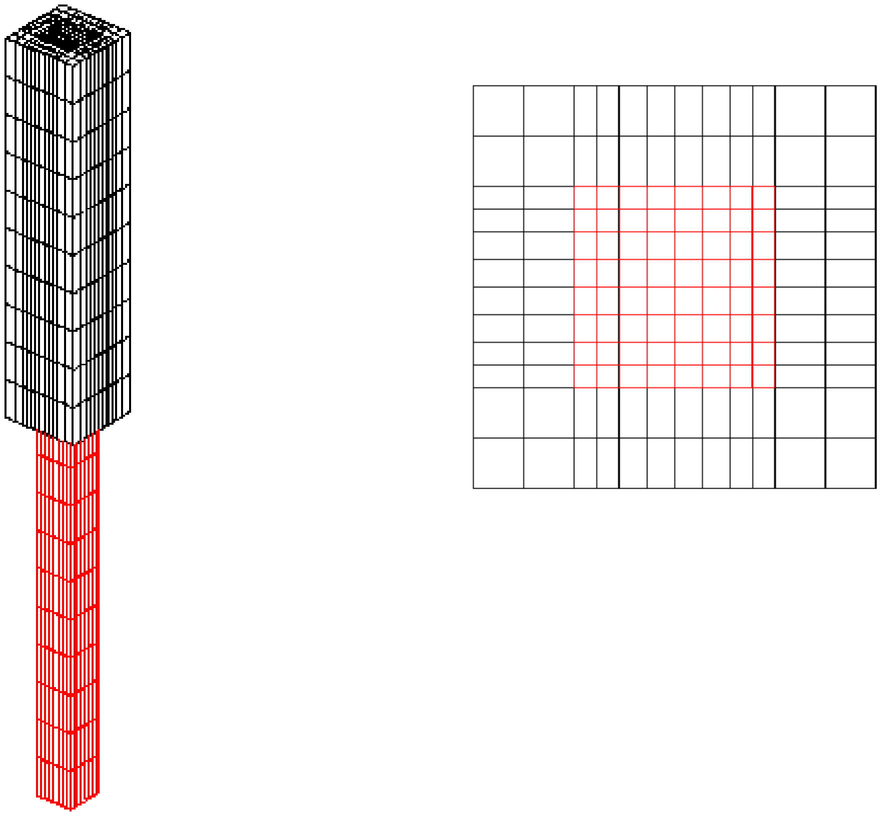
2 Reference solution

the reference solution was obtained by the French atomic energy agency with CASTEM 2000, a mesh containing 2080 cubic elements with 20 nodes and 100 cable elements.

3 Modelization A

3.1 Characteristic of the modelization

the beam out of concrete is represented by 2080 elements `MECA_HEXA8`, supported per as many meshes hexahedrons with 8 nodes. The 5 cables are represented using 20 elements `MECA_BARRE` each one supported per as many segments with 2 nodes. The figure below watch mesh of the beam.



Appear 3.1-a: Description of the mesh

concrete material is defined by behaviors `ELAS` and `BPEL_BETON` : the parameters characteristic of this relation are fixed at 0 because one does not wish to include the losses of tension due to the shrinking and the creep of the concrete.
The material steel for the cables is defined by behaviors `ELAS` and `BPEL_ACIER`. The non-zero values for `BPEL_ACIER` relate to friction ($FROT\_LINE=1,5\,10^{-3}m^{-1}$) and the elastic limit since a value zero is illicit ($SY=1,94\,10^{11}Pa$). The radius of the cables is of $2,8209\,10^{-2}m$.

The blocked degrees of freedom are the following:
DZ for the lower face
DX and DY the points located on the axis of symmetry of the beam
DX for the point $(0.5\,0.\,0.)$ and DY the point $(-0.5\,0.\,0.)$

the tension $F_0=3,75\,10^6 N$ is applied to the lower nodes of cables 1,2,3 and 4 and at the two ends for cable 5.

The loading is carried out into 4 time step:

- $t=150s$, taken into account of gravity: `STAT_NON_LINE` with the boundary conditions, gravity and the kinematic relations for all the cables. The cables not contributing to the stiffness of the model, one affects a constitutive law "SANS `to them`" (forced null)
- $t=300s$, put in tension of cables 1 and 2: `CALC_PRECONT` with the boundary conditions, cables 1 and 2 being cables to be put in tension, cables 3,4 and 5 inactive
- $t=450s$, being put in tension of cables 3 and 4: `CALC_PRECONT` with the boundary conditions, the kinematic relations for cables 1 and 2, cables 3 and 4 being cables to be put in tension, inactive cable 5
- $t=600s$, being put in tension of cable 5: `CALC_PRECONT` with the boundary conditions, the kinematic relations for cables 1,2,3 and 4, cable 5 being the cable to be put in tension.

3.2 Stages of computation

the main steps of computation correspond to the features which one wishes to validate:

- operator `DEFI_MATERIAU` : definition of behavior models `BPEL_BETON` with the default values and `BPEL_ACIER`, in the case of loss per linear friction,
- operator `DEFI_CABLE_BP` : determination of a profile of tension along the cable of prestressing, in taking into account the losses by linear friction and the losses by retreat of anchorage; computation of the coefficients of the kinematic relations between the degrees of freedom of the nodes of the cable and the degrees of freedom of the nodes "close" to the concrete beam, in the case of a beam modelled by elements $3D$,
- operator `AFFE_CHAR_MECA` : definition of a loading of the type `RELA_CINE_BP` `(RELA_CINE = ' OUI')`,
- operator `STAT_NON_LINE`, option `COMP_INCR` : computation of the state of equilibrium by taking account of the loading of the type `RELA_CINE_BP`, in the case of a beam modelled by elements $3D$,
- constitutive law `SANS`,
- macro-command `CALC_PRECONT` with a nonvirgin initial state, that there are or not inactive cables, that there are one or more cables to put in tension.

Moreover, one tests computation with the exact iterative method of Newton and approximate method `IMPLEX`. In this case test, one remains in elasticity; the results got by the two methods of resolution must thus be identical.

3.3 Results of the modelization A

One compares the value extracted the field `SIEF_ELNO` with the value of reference obtained with CASTEM
and this for various characteristic times (non-zero tension) and for nodes équirépartis along the cables.
The component to which the test relates is the tension in the cables N.
The tests are carried out 2 times, once when the problem is solved into implicit (`METHODE=' NEWTON'`) and once when the problem is solved with method `IMPLEX` (`METHODE=' IMPLEX'`). In both cases, the tolerances are identical.

3.3.1 Tension in cable 1

$T=300\,s$

Identification (node/mesh)	Standard of reference	Value of reference (N)	Tolerance ($\%$)
`N1 - M5655`	`"SOURCE_EXTERNE"`	3,648.106 N	0.10%
`N6 - M5660`	`"SOURCE_EXTERNE"`	3,675.106 N	0.10%
`N11 - M5664`	`"SOURCE_EXTERNE"`	3,693.106 N	0.10%
`N16 - M5670`	`"SOURCE_EXTERNE"`	3,667.106 N	0.10%
`N101 - M5674`	`"SOURCE_EXTERNE"`	3,640.106 N	0.10%

$T=450\,s$

Identification (node/mesh)	Standard of reference	Value of reference (N)	Tolerance ($\%$)
`N1 - M5655`	`"SOURCE_EXTERNE"`	3,561.106 N	1.00%
`N6 - M5660`	`"SOURCE_EXTERNE"`	3,588.106 N	1.00%
`N11 - M5664`	`"SOURCE_EXTERNE"`	3,628.106 N	1.00%
`N16 - M5670`	`"SOURCE_EXTERNE"`	3,645.106 N	1.00%
`N101 - M5674`	`"SOURCE_EXTERNE"`	3,629.106 N	1.00%

$T=600\,s$

Identification (node/mesh)	Standard of reference	Value of reference (N)	Tolerance ($\%$)
`N1 - M5655`	`"SOURCE_EXTERNE"`	3,519.106 N	1.00%
`N6 - M5660`	`"SOURCE_EXTERNE"`	3,546.106 N	1.00%
`N11 - M5664`	`"SOURCE_EXTERNE"`	3,597.106 N	1.00%
`N16 - M5670`	`"SOURCE_EXTERNE"`	3,635.106 N	1.00%
`N101 - M5674`	`"SOURCE_EXTERNE"`	3,614.106 N	1.00%

3.3.2 Tension in cable 3

$T=450\,s$

Identification (node/mesh)	Standard of reference	Value of reference (N)	Tolerance ($\%$)
`N41 - M5695`	`“SOURCE_EXTERNE”`	3,647.106 N	0.10%
`N46 - M5700`	`“SOURCE_EXTERNE”`	3,675.106 N	0.10%
`N51 - M5705`	`“SOURCE_EXTERNE”`	3,695.106 N	0.10%
`N56 - M5710`	`“SOURCE_EXTERNE”`	3,667.106 N	0.10%
`N103 - M5714`	`“SOURCE_EXTERNE”`	3,640.106 N	0.10%

$T=600\,s$

Identification (node/mesh)	Standard of reference	Value of reference (N)	Tolerance ($\%$)
`N41 - M5695`	`“SOURCE_EXTERNE”`	3,6075.106 N	1.00%
`N46 - M5700`	`“SOURCE_EXTERNE”`	3,6346.106 N	1.00%
`N51 - M5705`	`“SOURCE_EXTERNE”`	3,6720.106 N	1.00%
`N56 - M5710`	`“SOURCE_EXTERNE”`	3,6529.106 N	1.00%
`N103 - M5714`	`“SOURCE_EXTERNE”`	3,6241.106 N	1.00%

3.3.3 Tension in cable 5

$T=600\,s$

Identification (node/mesh)	Standard of reference	Value of reference (N)	Tolerance ($\%$)
`N81 - M5735`	`“SOURCE_EXTERNE”`	3,647.106 N	0.10%
`N86 - M5740`	`“SOURCE_EXTERNE”`	3,674.106 N	0.10%
`N91 - M5745`	`“SOURCE_EXTERNE”`	3,695.106 N	0.10%
`N96 - M5750`	`“SOURCE_EXTERNE”`	3,674.106 N	0.10%
`N105 - M5754`	`“SOURCE_EXTERNE”`	3,647.106 N	0.10%

4 Modelization B

4.1 Characteristic of the modelization

The mesh is identical to the modelization A .

The loading is also identical.
One includes simply a cone of diffusion at the final end of cable 1: the definite cone has a length of $1,5\,m$ and a radius of $20\,cm$, to validate the use of functionality `CONE` of `DEFI_CABLE_BP`.

4.2 Results of the modelization B

the results on the level of the tension of the cables are very only slightly modified, the tolerances are identical to the modelization A .

5 Summary of the results

One notes as the macro-command makes it possible to as well obtain the tension given by the BPEL (guaranteed by the procedure implemented by CASTEM) with a very good accuracy since the variation is lower than 0.1% , with the method of Newton as with method `IMPLEX`. In addition, the effect of the setting in tension of the cables on the rest of structure and in particular on the already tended cables, is completely satisfactory since the difference between the reference solution and Aster computation is lower than 1% , whereas the mesh of reference was quadratic and computation carried out here used the meshes linear ones.
The results are identical that computation is solved using the algorithm of Newton or with method `IMPLEX`. The introduction of a cone of diffusion does not modify the quality of computations.