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## FORMA42 - Practical works of the formation “Génie Civil”: setting in tension of a prestressed beam with variable section

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### Summary:

This test 3D is to implement the two techniques of setting in tension of cables of prestressed and to compare the solutions thus obtained.

In modeling *A*, all the cables are put in tension simultaneously at the beginning of calculation by using the operator simply `STAT_NON_LINE`.

In modelings *B* and *C* the idea is to use the operator `CALC_PRECONT`. In the first case, all the cables are put in tension simultaneously, in the second case, the phasage of the setting in prestressing is modelled.

The objective of the TP is to implement these various strategies and to compare the differences in results got in each case.

In all the cases, the conditions of connections between the cable and the concrete as well as the calculation of the tensions according to the BPEL91 are carried out thanks to the operator `DEFI_CABLE_BP`.

When the TP is carried out in limited time, it can be judicious to leave modeling *A*, and to carry out only modelings *B* and *C*.

## 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 plan below:

The section of each cable is of  $25 \text{ cm}^2$ .

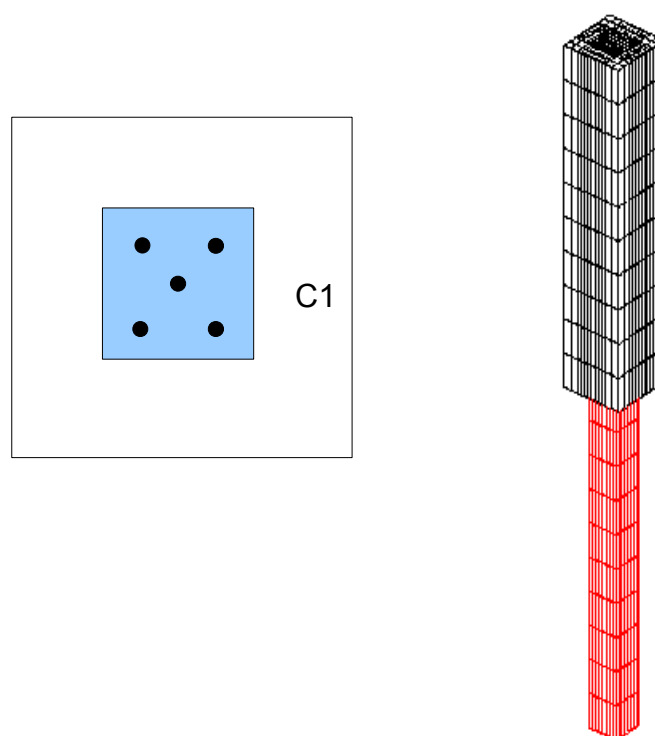


Figure 1: description of the grid used

### 1.2 Properties of materials

Material concrete constituting the beam:

- Young modulus:  $E_b = 4.10^4 \text{ MPa}$
- Poisson's ratio:  $\nu = 0,2$
- density:  $\rho = 2500 \text{ kg/m}^3$

Material steel constituting the cable:

- Young modulus:  $E_c = 1,93 \cdot 10^5 \text{ MPa}$
- Poisson's ratio:  $\nu = 0,3$
- density:  $\rho = 7850 \text{ kg/m}^3$

Characteristics concerning the setting in tension of the cables:

- retreat of anchoring:  $1 \text{ mm}$
- linear coefficient of friction:  $0,0015 \text{ m}^{-1}$
- force of tension at the end of a cable:  $3,75 \cdot 10^6 \text{ N}$
- age of dismantling: 150 days
- age of setting in tension of the first cable: 300 days

## 1.3 Boundary conditions and loadings

The base of the beam is blocked in the direction  $Z$ . 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 also subjected to gravity.

## 2 Modeling a: put in tension of the beam without taking into account of the phasage with STAT\_NON\_LINE

### 2.1 Implementation of the TP

In this part, one does not model the phasage, all the loadings are applied in a step of time.

- To import the grid with format MED (`ssnv164a.mmed`) and to visualize it
- To build the command file:
  - ◆ To see the grid with the format med: `LIRE_MALLAGE`
  - ◆ Creation of groups of nodes starting from groups of meshes: `DEFI_GROUP` on the groups of meshes 'SU3', 'PP', because one wishes to apply boundary conditions to these groups without the groups of node being created at the time of the grid.
  - ◆ Definition of the model: mmechanical odelisation  $3D$  for the group of mesh voluminal 'VOLTOT' (the complete beam) and mechanics of the type `BAR` for the groups of meshes cables ('CAB1', 'CAB2',...): `AFFE_MODELE`.
  - ◆ Definition of the wire specifications: the ray cables is worth  $R = 2.8209 \cdot 10^{-2} m$ , `AFFE_CARA_ELEM`, keyword `BAR`.
  - ◆ Creation of a material concrete ( $E = 4.E10 Pa$ ,  $\nu = 0.2$ ,  $\rho = 2500 kg/m^3$ ): `DEFI_MATERIAU` with keyword `ELAS` and `BPEL_BETON` (creep/withdrawal by default).
  - ◆ Creation of a material cables ( $E = 1.93E11 Pa$ ,  $\nu = 0.3$ ,  $\rho = 7850 kg/m^3$ ). To use an elastic law and lawful specifications of prestressing (keyword `BPEL_ACIER` with `F_PRG = 1940.E6`, `FROT_COURB = 0`, `FROT_LINE = 1.5 \cdot 10^{-3}`).
  - ◆ Assignment of the material concrete with 'VOLTOT' and of the material steel to the cables: `AFFE_MATERIAU`.
  - ◆ Definitions of the boundary conditions (loadings, blockings): `AFFE_CHAR_MECA`:
    - $DX = 0$  on the group of nodes 'PY';
    - $DY = 0$  on the group of nodes 'PX';
    - $DX, DY = 0$  on the group of nodes 'PP' previously created;
    - $DZ = 0$  on the group of nodes 'SU3';
    - to inform gravity (keyword `GRAVITY`).
  - ◆ Definition of the cables of prestressed: `DEFI_CABLE_BP`. For all the cables, to adopt an initial tension of  $3.75 \cdot 10^6 N$  and a retreat of anchoring of  $0.001 m$ ; active anchoring is that at the narrow end of the beam (e.g. 'PC1D' for the first cable), the liability at the broad end (e.g. 'PC1F' for the first cable).
  - ◆ `AFFE_CHAR_MECA` to define the relation between the cables and the concrete. Attention with establishing well the kinematic relation between cables and concrete (`RELA_CINE = ' OUI '`) and the loading related to prestressing (`SIGM_BPEL = ' OUI '`).
  - ◆ to define the list of moment which will be used to solve the mechanical problem using `DEFI_LIST_REEL`.
  - ◆ To define `STAT_NON_LINE` for mechanical calculation. The concrete and the cables are elastic.
  - ◆ To calculate with `CALC_CHAMP`, the variables which you wish post-to treat with *Salomé* (has minimum the constraints) and to print them with format `MED`.
  - ◆ To recover the efforts which will be applied in cable 1 using the order `RECU_TABLE`. Lbe Imprimer with `IMPR_TABLE`.

- ◆ To recover the efforts in the various cables after setting in tension of the cables of prestressed using `POST_RELEVE_T`. Lbe to print with `IMPR_TABLE`.
  - ◆ To compare the curves more easily, it is then advised to plot on the same graphics the voltage curve according to the curvilinear X-coordinate (1) such that defined in the operator `DEFI_CABLE_BP`, (2) with the initial step and (3) with the step of final time in the structure of data exit results of `STAT_NON_LINE`. For that, to use the operator `RECU_FONCTION` then `IMPR_FONCTION` (`FORMAT=' XMGRACE'`).
- Open the file produced by `IMPR_FONCTION` with `XMGRACE`. What do you notice?
  - You can then varier parameters as starter on the calculation of the tension of the cables: retreat of anchoring, active/passive anchorings, loss by relieving and to compare the tensions in the cables.

## 2.2 Sizes tested and results

One tests the tension in cable 1 in several nodes. The reference was obtained via a calculation CASTEM with  $t = 600s$ .

Identification (node/mesh)	Type of reference	Value of reference ( N )	Tolerance ( % )
N1 - M5655	'SOURCE_EXTERNE'	3,519.10 <sup>6</sup> NR	3.00%
N6 - M5660	'SOURCE_EXTERNE'	3,546.10 <sup>6</sup> NR	3.00%
N11 - M5664	'SOURCE_EXTERNE'	3,597.10 <sup>6</sup> NR	3.50%
N16 - M5670	'SOURCE_EXTERNE'	3,635.10 <sup>6</sup> NR	1,00%
N101 - M5674	'SOURCE_EXTERNE'	3,614.10 <sup>6</sup> NR	6.00%

## 3 Modeling b: put in tension of the beam without taking into account of the phasage with CALC\_PRECONT

### 3.1 Implementation of the TP

#### 3.1.1 Preliminary stage if modeling A has not summer carried out

To import the test FORMA42a in AsterStudy. To analyze the command file to understand the various stages.

A certain number of postprocessing for cable 1 are proposed in order to control:

- the tension calculated in DEFI\_CABLE\_BP according to the BPEL, N1\_I
- the tension which is applied, N1\_0,
- the tension after calculation of balance at moment 600, N1\_600.

To inform the output files necessary then to launch calculation. What do you note?

In the continuation of the TP, IL will act to see the differences in profile of tension obtained according to the mode of setting in tension, like detailed in the following paragraph.

#### 3.1.2 Passage de STAT\_NON\_LINE with CALC\_PRECONT

It is a question here of resuming the preceding study but of carrying out the setting in tension using the operator CALC\_PRECONT with the place of STAT\_NON\_LINE.

Changes to operate are the following:

- to modify AFFE\_CHAR\_MECA in order to more not seek to apply prestressing (SIGM\_BPEL='NON')
- to change STAT\_NON\_LINE in CALC\_PRECONT. To remove the loading related to the cables of prestressing, and to inform the keyword CABLE\_BP.

What do you notice on the final profile of tension?

### 3.2 Sizes tested and results

One tests the tension in cable 1 in several nodes. The reference was obtained via a calculation CASTEM with  $t = 600s$ .

Identification (node/mesh)	Type of reference	Value of reference ( N )	Tolerance ( % )
N1 - M5655	'SOURCE_EXTERNE'	3,519.10 <sup>6</sup> NR	4.00%
N6 - M5660	'SOURCE_EXTERNE'	3,546.10 <sup>6</sup> NR	4.00%
N11 - M5664	'SOURCE_EXTERNE'	3,597.10 <sup>6</sup> NR	3.00%
N16 - M5670	'SOURCE_EXTERNE'	3,635.10 <sup>6</sup> NR	1,00%
N101 - M5674	'SOURCE_EXTERNE'	3,614.10 <sup>6</sup> NR	1,00%

## 4 Modeling C: modeling of the phasage of setting in prestressing

### 4.1 Implementation of the TP

It is now a question of resuming the preceding study but of modelling the phasage of prestressing. This one is the following:

- At the beginning, the cables are not yet places from there (there is only the sheath), on the other hand it has there the effect of gravity on the concrete.
- Cables 'CAB1' and 'CAB2' are put in tension at the moment 300 days (other cables being inactive!!).
- Cables 'CAB3' and 'CAB4' are put in tension at the moment 450 days. At 600 days, one puts in tension cable 'CAB5'.

To modify the command file consequently and to compare the profiles of tensions in the cables compared to the preceding cases.

Actions/orders to be used:

- To duplicate them `DEFI_CABLE_BP` if necessary power to separately tighten the 3 groups of cables. Make in the same way for the loadings associated with these cables. These loadings should comprise only the connections kinematics.
- Modification of the list of moments for the calculation of prestressing: `DEFI_LIST_REEL`, values (0,150,300,450,600) days.
- Make a first `STAT_NON_LINE` for the calculation of gravity (1 pas de time). Attention, not to take into account the cables, it is appropriate to affect the law of behavior to them `WITHOUT`, which amounts applying a null Young modulus.
- To proceed then to 3 calls to `CALC_PRECONT` for the setting in successive tension of the cables. The boundary conditions change in the 3 cases.

Take again same postprocessings as previously but by plotting the curves at the various moments or has minimum with  $T = 600$  days.

Observe the differences obtained on the tensions in the cables and the state in constraint in the concrete.

### 4.2 Sizes tested and results

One tests the tension in cable 1 in several nodes. The reference was obtained via a calculation CASTEM with  $t = 600$ s .

Identification (node/mesh)	Type of reference	Value of reference ( N )	Tolerance ( % )
N1 - M5655	'SOURCE_EXTERNE'	3,519.10 <sup>6</sup> NR	1,00%
N6 - M5660	'SOURCE_EXTERNE'	3,546.10 <sup>6</sup> NR	1,00%
N11 - M5664	'SOURCE_EXTERNE'	3,597.10 <sup>6</sup> NR	1,00%
N16 - M5670	'SOURCE_EXTERNE'	3,635.10 <sup>6</sup> NR	1,00%
N101 - M5674	'SOURCE_EXTERNE'	3,614.10 <sup>6</sup> NR	1,00%

## 5 Summary of the results

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This test makes it possible to test three different manners to impose the setting in tension of the cables of prestressing. Each one of these manners leads to profiles of tension in the different cables and thus to different constraints in the concrete. The user must be conscious of the differences.

In addition, when one associates this calculation of the tension of the cable with a non-linear calculation, it is important not to cumulate the losses. Thus, if the concrete is modelled using a viscoelastic law, one will not have to take into account the losses by creep of the concrete in the calculation of the tension of the cable.

That the tension is far from being uniform, it should be also noted is all the interest of these operators compared to imposing a prestressing in the form of a predeformation or of a fictitious thermal field.