# Realization of a study civil engineer with cables of prestressing

**Summary:**

The purpose of this document is to give advices to carry out reinforced concrete studies with cables of prestressing. He gives information about the precautions of grid, the modes of enforcement of prestressing and the possibilities of phasage.

# 1 Introduction

The studies of Génie Civil are often rather complex to carry out insofar as they utilize modelings 3D, hulls, bars and several materials. This document tries to pool the experience gained on the subject by giving advices of methodology for the grid and the phase of modeling, concerning the prestressed structures.

The numeric work implementation of the tension requires some precautions of use, in particular in the case as of non-linear calculations, since the chronology of the loadings can impact the results. In this document, we see how to set up the orders to reproduce some examples of possible situations in reality.

# 2 Notice preliminary

In *Code_Aster*, the cables of prestressing are modelled by elements 1D (bars with 2 nodes). Their setting in tension is possible and consists in applying a nonworthless tension in these cables. Two alternatives exist to carry out this setting in tension. The first method consists to set up the conditions kinematics between the cable and the concrete, to calculate the tension along the cable and then to apply these loadings to the model (instantaneous loading) to seek the balance of the structure. Its disadvantage is that the tension which results from balance is generally weaker than that required by the user.

The second method is an improvement of the first: it guarantees that the tension with balance is exactly that required, but also allows the setting in successive tension of the cables to recreate the phasage of the setting in prestressed structure. The last interest of this method, it is the possibility of applying the tension of the cable in a gradual way, which can be necessary for behaviors of the non-linear type, in particular in the event of cracking of the concrete during the phase of setting in prestressing.

In both cases, the basic ingredients are the same ones (operator DEFI_CABLE_BP and AFFE_CHAR_MECA). The difference comes owing to the fact that in the first case, the setting in balance is made simply by one STAT_NON_LINE whereas in the second case, one uses the macro-order CALC_PRECONT who includes a certain number of handling of the model to ensure the setting in tension (cf [R7.01.02]).

# 3 First stage: grid

To carry out a calculation on a structure of civil engineer, it is necessary to net the concrete, and possibly the reinforcements as well as the cables of prestressing.

- The grid of the concrete can be carried out with any voluminal element in 3D or in 2D. The elements can be linear or quadratic.

- The reinforcements are obligatorily with a grid with *SEG2* whose nodes must be confused with those of the concrete. It thus should be thought of it when the concrete is netted. In addition, it is necessary to be vigilant if the concrete is with a grid with cubic elements in order to make well correspond all the nodes concrete located along the reinforcement with a node steel: in other words if the concrete is with a grid with quadratic elements, at the place where must pass a reinforcement, it is necessary to define 2 *SEG2* steel for a mesh concrete.

- The cables of prestressed must be with a grid with *SEG2* . On the other hand, it is not necessary to make coincide the nodes of the cable and the nodes concrete: the order DEFI_CABLE_BP indeed allows to also create connections kinematics which will bind the nodes of the cable with the nodes of the concrete of the surrounding mesh. On the other hand, that generates a large number of multipliers of Lagrange which will weigh down calculation. There is thus a compromise to find between facility to carry out the grid and cost of calculation.

- In order to be able to define the cables, it is necessary to have named the nodes of anchoring to each end of the cable.

# 4 Second phase: the setting in fact of the case

One details here the various stages of the setting in data of a standard prestressed concrete problem in *Code_Aster*. For each phase, one specifies the possible questions to be posed and information which should be provided. An example of application is proposed in appendix where one gives the various alternatives for the phase of resolution.

## 4.1 Reading and possible enrichments of the grid

To check that the nodes of anchoring are quite accessible (individually) by one GROUP_NO.
To create the possible groups of nodes or meshs for postprocessing.
To direct the groups of meshs correctly where one imposes loadings of type pressure or flow (order ORIE_PEAU_3D (2D) ).

## 4.2 Assignment of a model

At the present time, the reinforcements and the cables of prestressed can be modelled only by elements BAR (resting on *SEG2* ). For the concrete, the choice is much freer, on the other hand, should be noted the following limitations:

- in the presence of cable of prestressing, the use of DEFI_CABLE_BP authorize only the voluminal elements and modelings of plate (DKT, Q4GG) ;
- the operator CALC_PRECONT who in particular allows not to put all the cables in tension simultaneously is compatible with same modelings.

## 4.3 Characteristics of the elements of structure

To define the section of the passive reinforcements and the cables of prestressing.

## 4.4 Definition of materials

The laws of behavior available for the concrete are:

- ELAS,
- MAZARS local or not-local version [R7.01.08]
- ENDO_ISOT_BETON or not local local version [R7.01.04]
- ENDO_ORTH_BETON or not local local version [R7.01.09]
- BETON_DOUBLE_DP [R7.01.03]
- KIT_DDI to combine a mechanical model with a model of creep: BETON_DOUBLE_DP with GRANGER_FP, and its alternatives [R7.01.01] or MAZARS with BETON_UMLV_FP.

The laws of behavior available for steels are: about all the laws are usable with the elements bars, most usually used are:

- ELAS

- VMIS_CINE_LINE (plasticity with linear kinematic work hardening)
- VMIS_ISOT_LINE (plasticity with linear isotropic work hardening)
- VMIS_ISOT_TRAC (plasticity with isotropic work hardening given by a traction diagram)
- PINTO_MENEGOTTO

The choice of the law determines the keywords to inform under DEFI_MATERIAU.

In the presence of cables and to be able to use DEFI_CABLE_BP, it is also necessary to have informed:

- keywords BETON_BPEL (PERT_CREPT, PERT_RETR) for the meshs concrete,
- keywords ELAS and ACIER_BPEL (SY, FROT_LINE, FROT_COURB, MU0_RELAX, RELAX_1000) for the steel of the cables of prestressing.

All these parameters are not obligatory.

**Note:**

1) *The parameter SY request a special attention since as opposed to what one could wait, it does not intervene in a possible nonlinear calculation with the plasticity of the cables. SY informed under ACIER_BPEL corresponds to the Fprg parameter indicated in the regulation BPEL and which makes it possible to calculate the loss by relieving. To allow a calculation with plasticization, it is necessary to state the elastic limit with the selected law of behavior.*
2) *The order DEFI_CABLE_BP cannot consider the case where the elastic characteristics of the concrete crossed by the cable can vary with the temperature.*
3) *The order DEFI_CABLE_BP can support the case where a cable crosses several materials concrete. One however needs that all the concretes have the same properties with respect to the BPEL, i.e. the same properties under the keyword BPEL_BETON.*

## 4.5 Definition of the cables

The phase of definition of the cables places by the order DEFI_CABLE_BP. That makes it possible to define which must be the tension in the cables according to the rules of the BPEL, according to the initial tension, of the retreat of anchoring (which applies only for active anchorings), of the relieving of steel and the deformations differed from the concrete (creep and withdrawal).
Let us announce that only one DEFI_CABLE_BP can gather several cables provided that they have the same parameters of entry for the calculation of the tension, and that one wishes to tighten all these cables simultaneously.

The punching created by anchorings can some times cause digital difficulties of modeling. The origin of this problem is related to the incompatibility of the load pattern (a specific force created by anchoring) compared to the grid of the concrete ( 2D or 3D ). To avoid this problem, the keyword CONE under DEFI_CABLE_BP (available starting from V7 of *Code_Aster*) allows to define a volume representing the cone of fainding placed at the end of the cables, and thus to distribute the force of punching on a volume of the concrete, and either on one or, some nodes at the maximum. The geometry of this volume corresponds to a cylinder whose dimensions (length and ray) should correspond to the cone of fainding really employed. However it should be noted that if the grid of the concrete in this area is not sufficiently fine, the volume of the cone will not be able to integrate concrete nodes moreover. But under this condition the problem of stress concentration will be probably unimportant.

**Note:**

1) *Each end of cable can be declared as being "active" or "passive". If a cable does not comprise any active end, no tension is then applied.*
2) *The use of the option CONE a special attention as for the way requires of imposing the boundary conditions under penalty of seeing appearing conditions superabundant kinematics which prevent the resolution of the problem.*

## 4.6 Definition of the loadings

It is necessary to as many define separately (either calls to AFFE_CHAR_MECA (_F)) following loadings:

- Boundary conditions as well as the possible valid instantaneous loadings at the beginning of calculation
- The relations kinematics making it possible to connect the nodes cables with the nodes concrete: RELA_CINE_BP=_F(RELA_CINE=' OUI'). This loading is necessary for any calculation with STAT_NON_LINE on the model containing the cables of prestressed (if not fatal error due to matrix not factorisable).
  During the call to CALC_PRECONT, the connections kinematics should not be include in the loadings except when one carries out the setting in tension in several stages. It is indeed necessary to include the connections kinematics for the cables which were already put in tension by a first CALC_PRECONT : that thus relates to the cables which do not enter nor the keyword CABLE_BP nor in the keyword CABLE_BP_INACTIF (cf example in appendix and more particularly scenario 1). In this case, it is necessary to think of defining as much loading than of different phases of setting in tension.
- Posterior loadings with the setting in tension of the cables.

# 5 The resolution of the mechanical problem

It is a question here of specifying the loading to include (keyword EXCIT) at the time of the call to CALC_PRECONT. Several cases arise.

1) The user wishes to put in tension simultaneously all the cables of prestressed as well as an instantaneous loading, without other first loadings. In this case, it is enough to call on the macro-order only once CALC_PRECONT. The loading is composed of the boundary conditions and the possible instantaneous loadings. Under the keyword CABLE_BP, all the concepts will be included DEFI_CABLE_BP (see scenario 3 in appendix).

2) The user wishes to do calculations before the setting in tension of the cables. In this case, it is appropriate:
   1) that is to say not to include the cables in the model used to do the calculations before the setting in tension of the cables
   2) that is to say to use under the keyword BEHAVIOR of STAT_NON_LINE, the law of behavior RELATION=' SANS' for the meshs of the cable. In this case, it is essential to add in the loadings, the relations kinematics binding cable and concrete (obtained while writing AFFE_CHAR_MECA(RELA_CINE_BP=_F (RELA_CINE=' OUI'))) (see scenario 1 and 3 in appendix).

3) The user wishes successively to put in tension the cables. In this case, it is necessary to appeal with CALC_PRECONT as many times as necessary. CABLE_BP will contain the concepts DEFI_CABLE_BP associated with the cables which one is tending during this call to

CALC_PRECONT, CABLE_BP_INACTIF will contain those which one wishes to tighten later on. In this way, it is the macro-order which is given the responsibility to affect a law of behavior WITHOUT with these cables and to include the connections kinematics associated with these same cables.
For the loading, it is a question systematically of including the boundary conditions as well as the possible instantaneous loadings. From the second call to CALC_PRECONT, it is advisable to include moreover, the connections kinematics related to the cables already put in tension at the preceding stages (see scenario 1 in Appendix).

In all the cases, for STAT_NON_LINE who follow the setting in tension of the cables, it is important not to forget the whole of the connections kinematics related to the cables

**Note:**

*So for a reason or another, the user does not wish to use CALC_PRECONT to put in tension the cables of prestressing, it is possible to resort to the old method of setting in tension of the cables in spite of its disadvantages [R7.01.02]. The setting in tension is carried out simply by including in the loads the concept AFFE_CHAR_MECA defined by RELA_CINE_BP = F (RELA_CINE = 'YES', SIGM_BPEL=' OUI') . At the conclusion of this calculation, the tension in the cables is not equal any more to that prescribed by the BPEL. Nevertheless, it is possible to determine the coefficients of correction to apply to the initial tensions applied to the cables (on the level of the declaration of the operator DEFI_CABLE_BP ) allowing to compensate for overall the loss by instantaneous strain of the structure. Once the command file modified by these coefficients of correction, the modeling of the cables of prestressing is accomplished.*

*Attention, in the case of sequence of STAT_NON_LINE , it is appropriate starting from the second call, to include in the loading only the relations kinematics and not the tension in the cables, under penalty of adding this tension, with each calculation (see scenario 2 in appendix). That thus requires to create a second AFFE_CHAR_MECA with the operand RELA_CINE_BP = F (RELA_CINE = 'YES', SIGM_BPEL=' NON') (cf scenario 2 in Appendix).*

# 6 Appendix

Here an example of application inspired of the case test [V6.04.164] (SSNV164). It is about a post crossed by 5 cables, and the loading is composed of:

- gravity
- prestressing in the cables
- a pressure on the higher face

The setting in data is common, then one shows 3 scenarios to solve the problem:

**The first scenario** is most physical:

- taking into account of gravity
- setting in tension of cables 1 and 2
- setting in tension of cables 3 and 4
- setting in tension of cable 5
- pressurization

**The second scenario** is that which one applied before the development of the operator CALC_PRECONT (to version 6 of *Code_Aster*) and which is the method which remains recommended if a model is used DKT for the concrete

- taking into account of gravity and setting in tension of the 5 cables
- pressurization

**The third scenario** is identical to the second with regard to the order of application of the loadings but it uses the operator CALC_PRECONT and thus allows to have directly the lawful tension in the cables of prestressing

**The setting in fact of the case**

```
MY=LIRE_MAILLAGE (...)

MA=DEFI_GROUP (...)

MO=AFFE_MODELE (MAILLAGE=MA,
               AFFE= (_F (GROUP_MA=' VOLTOT',
                          PHENOMENE=' MECANIQUE',
                          MODELISATION=' 3D',),
                      _F (GROUP_MA= ('CAB1', 'CAB2',
'CAB3', '              CAB4', 'CAB5'),
                          PHENOMENE=' MECANIQUE',
                          MODELISATION=' BARRE',),),)

CE=AFFE_CARA_ELEM (MODELE=MO,
                   BARRE=_F (… ),)

MBETON=DEFI_MATERIAU (ELAS=_F (...),
                      BPEL_BETON=_F (),);

MCABLE=DEFI_MATERIAU (ELAS=_F (… ),
                      BPEL_ACIER=_F (SY=1.94E11,
                                     FROT_COURB=0.0,
                                     FROT_LINE=1.5E-3,),
                      ECRO_LINE = _F (…))

CMAT=AFFE_MATERIAU (…)


CAB_BP1=DEFI_CABLE_BP (MODELE=MO,
                       CHAM_MATER=CMAT,
                       CARA_ELEM=CE,
                       GROUP_MA_BETON=' VOLTOT',
                       DEFI_CABLE=_F (GROUP_MA=' CAB1',
                                      GROUP_NO_ANCRAGE=
('PC1D', 'PC1F',),),
                       TYPE_ANCRAGE= ('ACTIVE',
'PASSIVE',),
                       TENSION_INIT=3.75E6,
                       RECUL_ANCRAGE=0.001,);

CAB_BP2=DEFI_CABLE_BP (MODELE=MO,
                       CHAM_MATER=CMAT,
                       CARA_ELEM=CE,
                       GROUP_MA_BETON=' VOLTOT',
                       DEFI_CABLE=_F (GROUP_MA=' CAB2',
                                      GROUP_NO_ANCRAGE=
('PC2D', 'PC2F',),),
                       TYPE_ANCRAGE= ('ACTIVE',
'PASSIVE',),
                       TENSION_INIT=3.75E6,
                       RECUL_ANCRAGE=0.001,)

CAB_BP3=DEFI_CABLE_BP (MODELE=MO,
                       CHAM_MATER=CMAT,
                       CARA_ELEM=CE,
                       GROUP_MA_BETON=' VOLTOT',
                       DEFI_CABLE=_F (GROUP_MA=' CAB3',
                                      GROUP_NO_ANCRAGE=
('PC3D', 'PC3F',),),
                       TYPE_ANCRAGE= ('ACTIVE',
'PASSIVE',),
                       TENSION_INIT=3.75E6,
                       RECUL_ANCRAGE=0.001,)

CAB_BP4=DEFI_CABLE_BP (MODELE=MO,
                       CHAM_MATER=CMAT,
                       CARA_ELEM=CE,
                       GROUP_MA_BETON=' VOLTOT',
                       DEFI_CABLE=_F (GROUP_MA=' CAB4',
                                      GROUP_NO_ANCRAGE=
('PC4D', 'PC4F',),),
                       TYPE_ANCRAGE= ('ACTIVE',
'PASSIVE',),
                       TENSION_INIT=3.75E6,
                       RECUL_ANCRAGE=0.001,)

CAB_BP5=DEFI_CABLE_BP (MODELE=MO,
                       CHAM_MATER=CMAT,
                       CARA_ELEM=CE,
                       GROUP_MA_BETON=' VOLTOT',
                       DEFI_CABLE=_F (GROUP_MA=' CAB5',
```

Reading and enrichment of the grid. The creation of GROUP_NO bound to the cables is essential only for one possible postprocessing along those.

Definition of the models (3D for the concrete, BAR for the cables)

Geometrical characteristics (transverse) of the elements bars

Creation and assignment of characteristic materials for the cable and the concrete:
Concrete: rubber band + given lawful BPEL by default
Steel: rubber band +données lawful BPEL + given for plastic model to isotropic work hardening

Definition of the 5 cables of prestressing

**Note:**

*It is possible to gather:*
*CAB_BP1 and CAB_BP2 but too CAB_BP3 and CAB_BP4 since they have the same characteristics and are put in tension simultaneously.*

If all the cables are tended simultaneously (scenario 2 and 3), one can gather all the cables except the 5 from which anchorings are different (ACTIF/ACTIF against ACTIF/PASSIF).

```
                                    GROUP_NO_ANCRAGE=
('PC5D', 'PC5F',),),
                      TYPE_ANCRAGE= ('ACTIVE', 'ACTIVE',),
                      TENSION_INIT=3.75E6,
                      RECUL_ANCRAGE=0.001,)



AIR CONDITIONING =AFFE_CHAR_MECA (MODELE=MO,
                     DDL_IMPO =…,
                     GRAVITY =…)

CMCAB1=AFFE_CHAR_MECA (MODELE=MO,
                   RELA_CINE_BP=_F (CABLE_BP=CAB_BP1,
                                    SIGM_BPEL=' NON',
                                    RELA_CINE=' OUI',),)
CMCAB2=AFFE_CHAR_MECA (MODELE=MO,
                   RELA_CINE_BP=_F (CABLE_BP=CAB_BP2,
                                    SIGM_BPEL=' NON',
                                    RELA_CINE=' OUI',),)
CMCAB3=AFFE_CHAR_MECA (MODELE=MO,
                   RELA_CINE_BP=_F (CABLE_BP=CAB_BP3,
                                     SIGM_BPEL=' NON',
                                     RELA_CINE=' OUI',),)
CMCAB4=AFFE_CHAR_MECA (MODELE=MO,
                   RELA_CINE_BP=_F (CABLE_BP=CAB_BP4,
                                    SIGM_BPEL=' NON',
                                    RELA_CINE=' OUI',),)
CMCAB5=AFFE_CHAR_MECA (MODELE=MO,
                   RELA_CINE_BP=_F (CABLE_BP=CAB_BP5,
                                    SIGM_BPEL=' NON',
                                    RELA_CINE=' OUI',),);

PLMBO =AFFE_CHAR_MECA (MODELE=MO,
                     PRES_REP =_F (GROUP_MA = 'HIGH',
                                   CLOSE = 500,),)
FUNCTION = DEFI_FONCTION (NOM_PARA = 'INST',
                     VALE = (0. , 0. , 600. , 0. , 1000. ,
1.),)
```

**Creation of the loadings:**

boundary conditions and gravity

The connections kinematics connecting the cable to the concrete
(here `SIGM_BPEL=' NON'` , because one does not want to include in this loading the tension in the cables)

Posterior loadings with the setting in tension of the cables (here a pressure)

**Scenario 1**

```
LINST=DEFI_LISTE_REEL (VALE= (0.0, 150. , 300. , 450. ,
600. , 1000.),);

# STAGE 1: effect of gravity

RES1 = STAT_NON_LINE (MODELE=MO,
                      CHAM_MATER=CMAT,
                      CARA_ELEM=CE,
                            COMPORTEMENT= (_F (RELATION =
'ELAS',),
                                       _F (RELATION = 'WITHOUT',
                                         GROUP_MA= ('CABLE'),),),
                                       EXCIT = (_F (LOAD = AIR
CONDITIONING,),
                                        _F (LOAD = CMCAB1),
                                        _F (LOAD = CMCAB2),
                                        _F (LOAD = CMCAB3),
                                        _F (LOAD = CMCAB4),
                                        _F (LOAD = CMCAB5),),
                      INCREMENT=_F (LIST_INST = LINST,
                                    INST_FIN = 150.),)


# STAGE 2: setting in tension of cables 1 and 2
#------------------------------------------------------
RES1 =  CALC_PRECONT (reuse=RES1,
                      ETAT_INIT=_F (EVOL_NOLI=RES1),
                      MODELE=MO,
                      CHAM_MATER=CMAT,
                      CARA_ELEM=CE,
                      COMPORTEMENT= (_F (RELATION = 'ELAS',
                                         GROUP_MA=' VOLTOT',),
                         _F (RELATION = 'VMIS_ISOT_LINE',
                             GROUP_MA = 'CABLE'),),
                                   EXCIT=  (_F (LOAD = AIR
CONDITIONING,),),
                      CABLE_BP= (CAB_BP1, CAB_BP2),
                      CABLE_BP_INACTIF =
                            (CAB_BP3, CAB_BP4, CAB_BP5,),
                      INCREMENT=_F (LIST_INST = LINST,
                                    INST_FIN  = 300. ,),)

# STAGE 3: setting in tension cables 3 and 4
#------------------------------------------------------
RES1 = CALC_PRECONT (reuse=RES1,
                     ETAT_INIT=_F (EVOL_NOLI=RES1),
                     MODELE=MO,
                     CHAM_MATER=CMAT,
                     CARA_ELEM=CE,
                     COMPORTEMENT= (_F (RELATION = 'ELAS',
                                        GROUP_MA=' VOLTOT',),
                         _F (RELATION = 'VMIS_ISOT_LINE',
                             GROUP_MA = 'CABLE'),),
                              EXCIT    = (_F (LOAD = AIR
CONDITIONING,),
                                _F (LOAD = CMCAB1,),
                                _F (LOAD = CMCAB2,),),
                     CABLE_BP   = (CAB_BP3, CAB_BP4),
                     CABLE_BP_INACTIF = (CAB_BP5,),
                     INCREMENT=_F (LIST_INST = LINST,
                                   INST_FIN  = 450.),)

# STAGE 4: setting in tension cables 5
#------------------------------------------------------
RES1 = CALC_PRECONT (reuse=RES1,
                     ETAT_INIT=_F (EVOL_NOLI=RES1),
                     MODELE=MO,
                     CHAM_MATER=CMAT,
                     CARA_ELEM=CE,
                     COMPORTEMENT= (_F (RELATION = 'ELAS',
                                        GROUP_MA=' VOLTOT',),
                          _F (RELATION = 'VMIS_ISOT_LINE',
                              GROUP_MA = 'CABLE'),),
                              EXCIT    = (_F (LOAD = AIR
CONDITIONING,),
                                _F (LOAD = CMCAB1,),
                                _F (LOAD = CMCAB2,),
                                _F (LOAD = CMCAB3,),
                                _F (LOAD = CMCAB4,),),
```

The cables do not intervene: from where RELATION=' SANS' , but as they are present in the model, one includes the connections kinematics with regard to them (if not the cables “fall”).

Whereas the boundary conditions and gravity are maintained, CALC_PRECONT , will put in tension cables 1 and 2, while maintaining inactive cables 3.4 and 5.
To assign the real law of behavior to the cables.
Not to include the connections kinematics binding the cables to the concrete, CALC_PRECONT takes care some

This time cables 1 and 2 are already tended and thus are not managed any more by CALC_PRECONT , this is why it is necessary to include in the loading besides the boundary conditions, the connections kinematics for these 2 cables. On the other hand nothing to put for cable 5, always inactive, and for cables 3 and 4 that CALC_PRECONT will put in tension at this stage

Only cable 5 is managed by CALC_PRECONT , it is thus necessary to include the connections kinematics for the other already tended cables (1,2,3 and 4).

```
                      CABLE_BP   = (CAB_BP5,),
                      INCREMENT=_F (LIST_INST = LINST,
                                    INST_FIN = 600. ,),)
```

```
# STAGE  5: pressurization
#-----------------------------------------------------------
RES1 = STAT_NON_LINE (reuse=RES1,
                      ETAT_INIT=_F (EVOL_NOLI=RES1),
                      MODELE=MO,
                      CHAM_MATER=CMAT,
                      CARA_ELEM=CE,
                            COMPORTEMENT= (_F (RELATION =
'ELAS',
                                              GROUP_MA=' VOLTOT',),
                                  _F (RELATION = 'VMIS_ISOT_LINE',
                                      GROUP_MA = 'CABLE'),),
                                      EXCIT    = (_F (LOAD = AIR
CONDITIONING,),
                                        _F (LOAD = CMCAB1,),
                                        _F (LOAD = CMCAB2,),
                                        _F (LOAD = CMCAB3,),
                                        _F (LOAD = CMCAB4,),
                                        _F (LOAD = CMCAB5,),
                                        _F (LOAD = NEAR,
                                                   FONC_MULT =
FUNCTION,)),
                      INCREMENT=_F (LIST_INST = LINST,
                                    INST_FIN = 1000.),)
```

All the cables are now active. The loading must understand the boundary conditions, the loadings instantaneous, the connections kinematics for all the cables and the new loadings to be applied (here NEAR ).

**Scenario 2**

```
LINST=DEFI_LISTE_REEL (VALE= (0.0, 600. , 1000.),);

CMCAB1B=AFFE_CHAR_MECA (MODELE=MO,
                  RELA_CINE_BP=_F (CABLE_BP=CAB_BP1,
                                   SIGM_BPEL=' OUI',
                                   RELA_CINE=' OUI',),)
CMCAB2B=AFFE_CHAR_MECA (MODELE=MO,
                  RELA_CINE_BP=_F (CABLE_BP=CAB_BP2,
                                   SIGM_BPEL=' OUI',
                                   RELA_CINE=' OUI',),)
CMCAB3B=AFFE_CHAR_MECA (MODELE=MO,
                  RELA_CINE_BP=_F (CABLE_BP=CAB_BP3,
                                    SIGM_BPEL=' OUI',
                                    RELA_CINE=' OUI',),)
CMCAB4B=AFFE_CHAR_MECA (MODELE=MO,
                  RELA_CINE_BP=_F (CABLE_BP=CAB_BP4,
                                   SIGM_BPEL=' OUI',
                                   RELA_CINE=' OUI',),)
CMCAB5B=AFFE_CHAR_MECA (MODELE=MO,
                  RELA_CINE_BP=_F (CABLE_BP=CAB_BP5,
                                   SIGM_BPEL=' OUI',
                                   RELA_CINE=' OUI',),);
```

To directly apply the tension in the cables, one needs to define new loadings containing at the same time the connections kinematics binding cable and concrete, and the value of the tension to be included in the cables (from where `SIGM_BPEL=' OUI'` , contrary to the loadings `CMCABi` defined initially).

```
# STAGE 1: effect of gravity  + tension of the cables

RES1 = STAT_NON_LINE (MODELE=MO,
                      CHAM_MATER=CMAT,
                      CARA_ELEM=CE,
                      COMPORTEMENT= (_F (RELATION = 'ELAS',
                                         GROUP_MA=' VOLTOT',),
                                                 _F (RELATION =
'VMIS_ISOT_LINE',
                                  GROUP_MA = 'CABLE',),
                                  EXCIT    = (_F (LOAD = AIR
CONDITIONING,),
                                   _F (LOAD = CMCAB1B),
                                   _F (LOAD = CMCAB2B),
                                   _F (LOAD = CMCAB3B),
                                   _F (LOAD = CMCAB4B),
                                   _F (LOAD = CMCAB5B),),
                     INCREMENT=_F (LIST_INST = LINST,
                     INST_FIN = 600.),)
```

The loading is composed of `Air conditioning` and of `CMCAB`*`I`*`B` containing the connections kinematics and the tension in the cables

```
# STAGE  2: pressurization
#-----------------------------------------------------------
RES1 =  STAT_NON_LINE (reuse=RES1,
                       ETAT_INIT=_F (EVOL_NOLI=RES1),
                       MODELE=MO,
                       CHAM_MATER=CMAT,
                       CARA_ELEM=CE,
                             COMPORTEMENT= (_F (RELATION =
'ELAS',
                                                GROUP_MA='
VOLTOT',),
                                               _F (RELATION =
'VMIS_ISOT_LINE',
                                  GROUP_MA = 'CABLE',),
                                   EXCIT    = (_F (LOAD = AIR
CONDITIONING,),
                                      _F (LOAD = CMCAB1,),
                                      _F (LOAD = CMCAB2,),
                                      _F (LOAD = CMCAB3,),
                                      _F (LOAD = CMCAB4,),
                                      _F (LOAD = CMCAB5,),
                                      _F (LOAD = NEAR,
                                                 FONC_MULT =
FUNCTION,)),
                       INCREMENT=_F (LIST_INST = LINST,
                                     INST_FIN = 1000.),)
```

One always maintains the boundary conditions and gravity, one includes the pressure. For the cables, it is well them `CMCAB`*`I`* because one just wishes to maintain the connections kinematics (if not, one adds once again the tension in the cables)

**Scenario 3**

```
LINST=DEFI_LISTE_REEL (VALE= (0.0, 600. , 1000.),);

# STAGE 1: effect of gravity + tension of the cables

RES1 = CABLE_PRECONT (MODELE=MO,
                      CHAM_MATER=CMAT,
                      CARA_ELEM=CE,
                      COMPORTEMENT= (_F (RELATION = 'ELAS',
                                         GROUP_MA=' VOLTOT',),
                                          _F  (RELATION =
'VMIS_ISOT_LINE',
                                    GROUP_MA = 'CABLE'),),
                      CABLE_BP = (CAB_BP1, CAB_BP2,
                                  CAB_BP3, CAB_BP4, CAB_BP5),
                                   EXCIT     =_F  (LOAD =  AIR
CONDITIONING,),
                      INCREMENT=_F (LIST_INST = LINST,
                                    INST_FIN = 600.),)


# STAGE 2: pressurization
#-------------------------------------------------------
RES1 = STAT_NON_LINE (reuse=RES1,
                      ETAT_INIT=_F (EVOL_NOLI=RES1),
                      MODELE=MO,
                      CHAM_MATER=CMAT,
                      CARA_ELEM=CE,
                            COMPORTEMENT=  (_F  (RELATION =
'ELAS',
                                                GROUP_MA=' VOLTOT',),
                                                 _F  (RELATION='
VMIS_ISOT_LINE',
                                          GROUP_MA = 'CABLE'),),
                                        EXCIT     = (_F  (LOAD =  AIR
CONDITIONING,),
                                          _F (LOAD = CMCAB1,),
                                          _F (LOAD = CMCAB2,),
                                          _F (LOAD = CMCAB3,),
                                          _F (LOAD = CMCAB4,),
                                          _F (LOAD = CMCAB5,),
                                          _F (LOAD = NEAR,
                                                       FONC_MULT =
FUNCTION,)),
                      INCREMENT=_F (LIST_INST = LINST,
                                    INST_FIN = 1000.),)
```

The loading is composed of `Air conditioning` and the 5 cables are put in tension simultaneously

One always maintains the boundary conditions and gravity, one includes the pressure. For the cables, one always needs the connections kinematics with regard to them.