Macro-command DEFI_CABLE_BP

Summarized

the purpose of this command is to calculate the initial profiles of tension along the cables of prestressed of one concrete structure. The data of computation are the tension applied at the ends and other parameters characteristic of the anchorages and materials. The relations used are those prescribed by the BPEL 91 or the ETCC.

The concept cabl_precont product can then be used:

- is by the operator AFFE_CHAR_MECA [U4.44.01] operand RELA_CINE_BP to define the mechanical loadings related to the presence of the cable (kinematic relations and/or tension in the cables). These loadings will be taken into account by the operator STAT_NON_LINE [U4.51.03].

–that is to say by the operator CALC_PRECONT [U4.42.05] for a setting in progressive tension of the cables and the possibility of making phasage.

Product Data format of cabl_precont type.

1 Syntax

```
cabl_pr    [cabl_precont] = DEFI_CABLE_BP   (

    ♦ MODELE=modele                       ,              [model]
    ♦ CHAM_MATER=chmat                ,                  [cham_mater]
    ♦ CARA_ELEM=caelem                    ,              [cara_elem]
    ♦ GROUP_MA_BETON=grmabe               ,              [gr_maille]

    ♦ DEFI_CABLE=_F           (

        ♦ /GROUP_MA                 =grmaca  ,           [gr_maille]
          /MAILLE                      =l_maca  ,        [l_maille]

        ♦ /NOEUD_ANCRAGE               =l_noa   ,            [l_noeud]
          /GROUP_NO_ANCRAGE            =l_gnoa  ,        [l_gr_noeud]

        ◊TENSION_CT=                 counts          [table_*])

   ♦TYPE_ANCRAGE=l_tya                    ,              [l_tx]
   ♦TENSION_INIT=f0                   ,                  [R]
   ♦RECUL_ANCRAGE=delta                       ,              [R]

   ◊TYPE_RELAX        =          /"SANS"           [DEFAULT]
                                 /"BPEL"
                                 /"ETCC_DIRECT"
                                 /"ETCC_REPRISE"


   ◊CONE=_F                   (

         ♦  RAYON=rayon                       ,              [R]
         ♦LONGUEUR=long                       ,              [R]
         ♦PRESENT=l_pre                       ,              [l_tx])

   ◊TITER=l_titr                              ,          [l_tx]

# If TYPE_RELAX=' BPEL',

   ♦R_J=rj                            ,                      [R]

# If TYPE_RELAX=' ETCC_DIRECT' or "ETCC_REPRISE",

   ♦NBH_RELAX=nbh                         ,              [R]

 )
```

2 Operands

2.1 MODEL Operand

♦MODELE = by the operator

models Product concept AFFE_MODELE [U4.41.01] making it possible to define element types the finished affected ones in meshes of the mesh.

2.2 Operand CHAM_MATER

♦CHAM_MATER = chmat

Product concept by the operator AFFE_MATERIAU [U4.43.02] allowing to meshes assign materials to mesh.

2.3 Operand CARA_ELEM

♦CARA_ELEM = caelem

Product concept by the operator AFFE_CARA_ELEM [U4.42.01] allowing to assign mechanical and geometrical characteristics to the elements of studied structure.

2.4 Operand GROUP_MA_BETON

♦ GROUP_MA_BETON = grmabe

Name of (or of) the mesh groups of the mesh representing concrete structure. One thus precisely defines the locus of projection of the cables, preliminary stage to the determination of the kinematic relations between the degrees of freedom of the nodes of the cables and the degrees of freedom of the nodes of concrete structure.

Note:

1 - It is possible to provide a list of mesh group here, in particular for the case where all meshes the concrete surrounding the cable do not have the same behavior. However, it is essential that all meshes the concretes concerned have same characteristics BPEL_BETON *.*
2 - meshes modelling the concrete can be only meshes 3D or meshes 2D in the case of a modelization of plate (DKT, Q4GG).

2.5 Key word DEFI_CABLE

♦DEFI_CABLE

Factor key word allowing the definition of a cable by designation of the topological entities of the mesh which represent it. The multiple occurrences are authorized, in order to be able to define several cables.

♦/GROUP_MA = grmaca

Name of the mesh group of the mesh representing the cable.

/MAILLE = l_maca

List of meshes of the mesh representing the cable. Incompatible functionality with the key word CONE (to use GROUP_MA).

♦/NOEUD_ANCRAGE = l_noa

List of the nodes defining the anchorages of the cable, i.e ends. This list must comprise 2 arguments, neither more nor less. /GROUP_NO_ANCRAGE

= l_gnoa List

of nodes groups defining the anchorages. The cardinal of this list must be lower or equal to 2. In each group of node, one will retain like anchorage only the first node of the group. ◊

`TENSION_CT = array Counts`

containing the tension in the cable for all the curvilinear abscisses (array with 2 columns). This array is used to compute: the losses by relaxation of steel if the user chose for the option TYPE `_RELAX = "ETCC_REPRISE". This` array is obtained via a POST `_RELEVE_T on` the nodes of the studied cable, after the first static computation. Operand

2.6 TYPE_ANCRAGE ♦

`TYPE_ANCRAGE = l_tya List`

of arguments of type text characterizing the anchorages of the cable: " `ACTIF" or` " `PASSIF"` `(only` licit arguments). This list must comprise 2 arguments, neither more nor less, and must be ordered compared to the list of the nodes defining the anchorages (operand NOEUD_ANCRAGE `above`). It should be noted that if several cables are defined in DEFI_CABLE `then` the first argument of TYPE_ANCRAGE applies to all the first nodes which define the anchorages. Idem for the second argument. Note:

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1 -

the operator meshes reconstitutes the driving related path of the first to the second anchorage of the cable while traversing which represent it. Nonthe existence of a related path between the two anchorages causes a program stop in fatal error. 2 -
the active anchorages are those where an initial tension is applied. Operand

2.7 TENSION_INIT ♦

`TENSION_INIT = f0 Valeur`

of the initial force applied to the active anchorages of the cables. This
value must be positive. Operand

2.8 RECUL_ANCRAGE ♦

`RECUL_ANCRAGE = delta Value`

of the retreat to the active anchorages of the cables. This
value must be positive. Choice

2.9 of the type of computation for the taking into account of the relaxation of steels Factor key word

allowing to determine whether one takes into account or not, the losses of tension by relaxation of steel, and so yes which is the method of calculating used. This factor key word being optional, by defaults the losses of tension by relaxation of steel are not taken into account. TYPE

2.9.1 `_RELAX=' SANS' It`

acts of the default value. In this case, one does not take into account this kind of loss. TYPE

2.9.2 `_RELAX=' BPEL' In this case,`

the formula of the BPEL is applied, and key word R_J `must` be indicated (cf §2.102.10 the detail). TYPE

2.9.3 `_RELAX=' ETCC_DIRECT' In this case,`

the formula of the ETCC is applied, but the force used takes into account only the losses by friction and retreat of anchorage (cf § 4) 4 It
is necessary to inform key word NBH _RELAX (cf §2.112.11 TYPE

2.9.4 _RELAX=' ETCC_REPRISE' In this case,

the formula of the ETCC is applied. The force used is that provided by the user under factor key word DEFI _CABLE/TENSION_CT= counts. The tension thus taken into account can take account of the elastic losses if the cables were put in prestressed in 2 families. It
is necessary to inform key word NBH _RELAX (cf §2.112.11 Operand

2.10 R_J ◊

R_J = Parameter rj

with informing only if TYPE _RELAX=' BPEL'. Value
of the adimensional function characterizing $r(j)$ the evolution of the relaxation of steel in time and only of steel (this coefficient does not apply to the losses by creep or shrinking of the concrete indicated under BPEL_BETON in DEFI _MATERIAU); for example the BPEL 91 recommends: with

$$r(j)=\frac{j}{j+9\times r_m}$$ in j days and

This $$r_m=\frac{\text{aire de la section de béton}}{\text{périmètre de la section de béton}}\equiv\text{rayon moyen}$$

value must be positive or null. corresponds

j to the date (in days) for which one wants to estimate the stress state in structure. For the case where, in the structural analysis, the bars would be modelled with a behavior of type creep, one should not inform this key word in DEFI _CABLE_BP. Operand

2.11 NBH_RELAX ◊

NBH_RELAX = formula nh

with informing only if TYPE _RELAX=' ETCC_DIREC' or "ETCC _REPRISE". Time considered for the taking into account of the losses by relaxation of steel in the ETCC (used if TYPE _RELAX=' ETCC_DIRECT' or "ETCC_REPRISE"), expressed of many hours.
The formula applied is the following one: formulate

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

: is

ρ_{1000} the value of the coefficient of relaxation of steel at 1000 hours in %, well informed under ETCC _ACIER. is

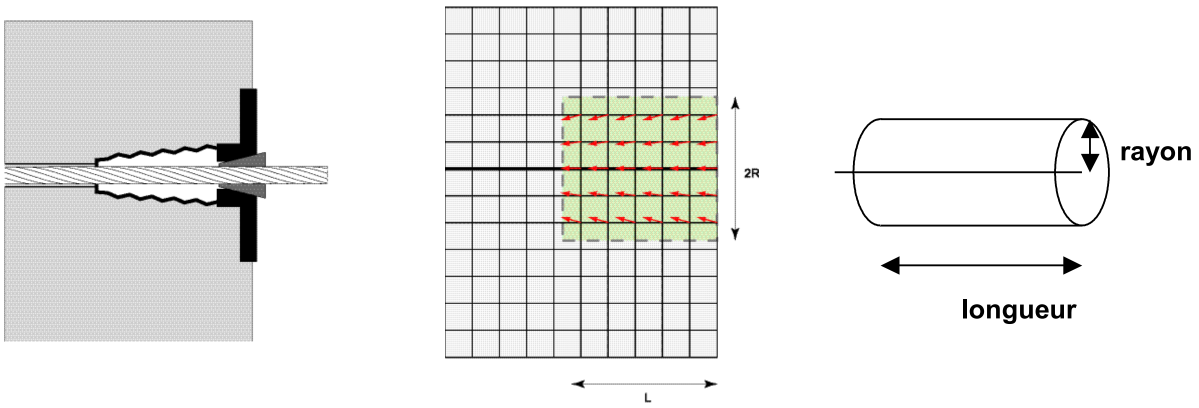
F_{prg} the maximum stress of steel with fracture, well informed under ETCC _ACIER. formula

F_i equal to the tension calculated according to the ETCC in taking into account the losses by friction and retreat of anchorage if TYPE _RELAX=' ETCC_DIRECT' or the power provided by the user under DEFI _CABLE/TENSION_CT if TYPE _RELAX=' ETCC_REPRISE'. Key word

2.12 CONE ♦

CONE This

factor key word makes it possible to define a geometrical volume around the anchorages, and to affect, in output of AFFE_CHAR_MECA key word RELA_CINE_BP , with all the nodes (concrete and cable) contained in this volume, a kinematic relation of the type LIAISON_SOLIDE (rigid body). The definition of this volume makes it possible to attenuate the stresses which the tensions at the ends of the cables generate on the concrete. In reality, this phenomenon is avoided thanks to the installation of a cone of diffusion of stress (material tougher than the concrete) which distributes the force of prestressed on a large surface of the concrete. In practice, the cone being practically right, one defines a cylindrical volume. Figure



Situation réelle **Modélisation EF**

1: 1 of a cone of diffusion: real situation and modelization It should be noted that

several rigid cones and thus several blocks are defined if key word PRESENT contains two " OUI" (a block per end of the cable) and/or if several cables are defined under DEFI_CABLE . Note:

In practice

, the cylinder is defined by the command DEFI_GROUP option TUNNEL . The methodology of extraction of the nodes contained in the cone is described in the document [U4.22.01] (command DEFI_GROUP) . ♦

RADIUS = radius Radius

of the cone. ♦

LONGUEUR = length Length

of the cone, with the meaning curvilinear abscisse on the cable. One defines the cone as a succession of cylinder while stopping when the overall length of the cylinders is equal to the parameter length . ♦

PRESENT = l_pre This

list must comprise 2 arguments, neither more nor less, and must be ordered compared to the list of the nodes defining the anchorages (operand NOEUD_ANCRAGE GROUP_NO_ANCRAGE above).
The only valid arguments are " YES" or " NON"; they make it possible to define the cone on the two anchorages (PRESENT = ("YES", "YES",)), on the first anchorage (PRESENT = ("YES", "NON",)) or on the second anchorage (PRESENT = ("NON", "YES",)). It should be noted that if several cables are

defined in DEFI_CABLE then the first argument of PRESENT applies to all the first nodes which define the anchorages. Idem for the second argument. Operand

2.13 TITER ◊

TITER = l_titr List

of arguments of type text defining a title attached to the concept [cabl _precont]. Theoretical

3 complement: estimate of the losses of tension in a cable of prestressed according to the regulations of the BPEL If

the user defined characteristic materials BPEL_BETON and BPEL_ACIER , the evolution of the tension (in Newton) along a cable of prestressing is calculated by means of the relations prescribed by the BPEL. These relations are the following ones: Evolution

3.1 of the tension in the vicinity of the anchorage where

$$F(s)=\tilde{F}(s)-\{x_{flu}\times F_0+x_{ret}\times F_0+r(j)\times\frac{5}{100}\times\rho_{1000}\left[\frac{\tilde{F}(s)}{S_a\times\sigma_y}-\mu_0\right]\times\tilde{F}(s)\}$$

s the curvilinear abscisse along the cable indicates. The parameters introduced into this statement are: initial

- F_0 tension (N); standard rate
- x_{flu} of loss of tension per creep of the concrete, compared to the initial tension; standard rate
- x_{ret} of loss of tension per shrinking of the concrete, compared to the initial tension; relaxation
- ρ_{1000} of steel at 1000 hours, expressed in %; area
- S_a of the cross-section of the cable defined in AFFE_CARA_ELEM ; stress
- σ_y yield stress of steel; adimensional
- μ_0 coefficient of relaxation of prestressed steel. Table

3.1 3.1-1

$r(j)$ an adimensional function characterizing the evolution of relaxation in time: with

$$r(j)=\frac{j}{j+9\times r_m}\text{ J in days and }r_m=\frac{\text{aire de la section de béton}}{\text{périmètre de la section de béton}}\equiv\text{rayon moyen}$$

the function geometry dependant $r(j)$ of structure, the value used is defined in operator DEFI _CABLE_BP. is

$\tilde{F}(s)$ the evolution of the tension in the vicinity of the anchorage after taking into account of the loss by retreat of anchorage and the losses by contact between the cable and the concrete.
$\tilde{F}(s)$ is defined by the relation: indicate $F_c(s)\times\tilde{F}(s)=[F_c(d)]^2$

$F_c(s)$ the evolution of the tension along the cable after taking into account of the losses by contact between the cable and the concrete: indicate $F_c(s)=F_0\exp(-f\ \alpha-\varphi s)$

α the angular deviation cumulated and the parameters introduced into the statement of are $F_c(s)$: coefficient of kinetic friction

- f of the cable on the partly curved concrete, in rad-1; coefficient of kinetic friction
- φ per unit of length. Note:

> - *The coefficients are f, φ, ρ_{1000}, σ_y, μ_0 with being informed in operator DEFI* `_MATERIAU under` *key word BPEL_ACIER , and*
> - *x_{flu} are x_{ret} with being informed in operator DEFI* `_MATERIAU under` *key word BPEL_BETON .*

The length intervening d in the statement of is $\tilde{F}(s)$ the length to which the loss of tension by retreat applies to the anchorage. This length is estimated using the relation: where

$$E_a S_a \Delta=\int_0^d \left(F_c(s)-\tilde{F}(s) \right) ds$$

is E_a the Young modulus of steel and Δ the value of the retreat to the anchorage. Thus $E_a S_a \Delta$ strain energy (cable) due to the retreat with the anchorage represents. Evolution

3.2 of the tension beyond the length where the losses of tension by retreat apply to the anchorage with

$$F(s)=F_c(s)-\{x_{flu}\times F_0+x_{ret}\times F_0+r(j)\times\frac{5}{100}\times\rho_{1000}\left[\frac{\tilde{F}(s)}{S_a\times\sigma_y}-\mu_0\right]\times\tilde{F}(s)\}$$

the same notations as those introduced in the preceding paragraph. Theoretical

4 complement: estimate of the losses of tension in a cable of prestressed according to the regulations of the ETCC If

the user defined characteristic materials ETCC `_BETON and` ETCC `_ACIER`, the evolution of the tension (in Newton) along a cable of prestressing is calculated by means of the relations prescribed by the ETCC. However the losses due to the elastic strain of the concrete and the strains due to the shrinking and the creep of the concrete are not taken into account in computation. It is appropriate if one wants to take them into account: of
−tightening the cables in 2 families to recover the losses due to the elastic strain of the concrete
−to impose on the concrete the strains shrinkage and of creep, after the setting in tension of the cables.

The established relations are the following ones. Evolution

4.1 of the tension in the vicinity of the anchorage formulates

$$F(s)=\tilde{F}(s)-0,8\times 0,66\,\rho_{1000}.\exp^{9,1\tilde{F}(s)/F_{prg}}.\left(\frac{nh}{1000}\right)^{0,75(1-\tilde{F}(s))/F_{prg}}.10^{-5}\tilde{F}(s)$$

Object s the curvilinear abscisse along the cable. The parameters introduced into this statement are: formulate

- ρ_{1000} of steel at 1000 hours, expressed in %. Stress
- F_{prg} with fracture in steel.
- nh The number of hours after the setting into prestressed to which the losses are calculated. Table

4.1 4.1-1

$\tilde{F}(s)$ the evolution of the tension in the vicinity of the anchorage after taking into account of the loss by retreat of anchorage and the losses by contact between the cable and the concrete. formula

$\tilde{F}(s)$ is defined by the relation: formulate $F_c(s)\times\tilde{F}(s)=[F_c(d)]^2$

$F_c(s)$ the evolution of the tension along the cable after taking into account of the losses by contact between the cable and the concrete: formulate $F_c(s)=F_0\exp^{-\mu(\alpha+ks)}$

α the angular deviation cumulated and the parameters introduced into the statement of sonformule $F_c(s)$: formulate

- μ the coefficient of kinetic friction of the cable on the concrete; line
- $k[m^{-1}]$ the loss ratio in L

Note:

- *The coefficients formula μ, k, $\rho_{1000,}F_{prg}$ with being informed in operator DEFI `_MATERIAU under` the key word BPEL_ACIER , formula*
- *nh with being informed in operator DEFI `_CABLE_BP`.*

The length formulates d in the statement deformule $\tilde{F}(s)$ the length to which the loss of tension by retreat applies to the anchorage. This length is estimated using the relation: formulate

$$E_a S_a \Delta=\int_0^d \left(F_c(s)-\tilde{F}(s)\right)ds$$

formula E_a the Young modulus of steel and formula Δ the value of the retreat to the anchorage. Thus formula $E_a S_a \Delta$ strain energy (cable) due to the retreat with the anchorage. Evolution

4.2 of the tension beyond the length where the losses of tension by retreat apply to the anchorage formulates

$$F(s)=F_c(s)-0,8*0,66\,\rho_{1000}.\exp^{9,1F_c(s)/F_{prg}}.\left(\frac{nh}{1000}\right)^{0,75(1-F_c(s))/F_{prg}}.10^{-5}F_c(s)$$

the same notations as those introduced in the preceding paragraph. Example

5 See

test SSNV164 for an application, and the documents [U2.03.06] and [U 4.42.05] to know more precisely how to put in tension the cables of prestressing. See
test SSNV229 for an example of taking into account of the relaxation of steel according to the ETCC.