Operator DEFI_MATER_GC

1 Goal

The operator DEFI_MATER_GC allows to define the material parameters used for studies of civil engineer.

The objective is to help the user to define the parameters materials starting from more physical size.

In this order, the physical properties are informed (elastic, yield stress coefficients, characteristic resistances,…), at exit one has a concept material, which one can then assign to the various meshs with the order AFFE_MATERIAU.

Product a structure of data of the type to subdue.

Contents

2 General syntax

```
to subdue [to subdue] = DEFI_MATER_GC (
       ◊ INFORMATION   =/1                                          [Defect]
                         /2
       ♦/ MAZARS = _F (
          ♦ CODING = [‘BAEL91’, ‘EC2’, ‘TEST’]                       [Text]

           # if CODING  = ‘BAEL91’
          ♦ UNITE_CONTRAINTE = [‘MPa’|' Pa']                         [Text]
          ♦ FCJ              = fcj                                   [Reality]

           # if CODING  = ‘EC2’
          ♦ UNITE_CONTRAINTE = [‘Mpa’|' Pa']                         [Text]
          ♦ CLASS = [‘C12/15’|' C16/20'|' C20/25'|
                     ‘C25/30’|' C30/37'|' C35/45'|
                     ‘C40/50’|' C45/55'|' C50/60'|
                     ‘C55/67’|' C60/75'|' C70/85'|
                     ‘C80/95’|' C90/105']                             [Text]

           # if CODING  = ‘TEST’
           ♦ FCJ      = fcj                                          [Reality]
          ♦ EIJ      = eij                                           [Reality]
          ♦ EPSI_C   = epsi_c                                        [Reality]
          ♦ FTJ      = ftj                                           [Reality]
          ◊ NAKED       = naked                                      [Reality]
          ◊ EPSD0    = epsid0                                        [Reality]
          ◊ K        = K                                             [Reality]
          ◊ AC       = ac                                            [Reality]
          ◊ BC       = bc                                            [Reality]
          ◊ AT       = At                                            [Reality]
          ◊ BT       = BT                                            [Reality]
           # For postprocessing
          ◊ SIGM_LIM = sigmlim                                       [Reality]
          ◊ EPSI_LIM = epsilim                                       [Reality]
       )

       ♦/ENDO_FISS_EXP = _F (
          ♦ E              = E                                       [Reality]
          ♦ NAKED             = naked                                [Reality]
          ♦/FT           = ft                                        [Reality]
            /FT_FENDAGE   = ft_fendage                               [Reality]
          ♦ FC             = FC                                      [Reality]
          ♦ GF             = Gf                                      [Reality]
          ♦/P            = p                                         [Reality]
            /DSIG_DU      = dsdu                                     [Reality]
          ◊/Q            = Q                                         [Reality]
            /Q_REL        = q_rel                                    [Reality]
          ♦ LARG_BANDE     = dble_D                                  [Reality]
          ◊ COEF_RIGI_MINI = Rmin                                    [Reality]
       )
```

```
    ♦/STEEL  = _F (
      ♦ E           = Young                             [Reality]
      ♦ SY           = sigy                             [Reality]
      ◊ NAKED           = naked                         [Reality]
      ◊ D_SIGM_EPSI = dsde                              [Reality]
       # For postprocessing
      ◊ SIGM_LIM    = sigmlim                           [Reality]
      ◊ EPSI_LIM    = epsilim                           [Reality]
    )

    ◊ RHO         = rho                                 [Reality]
    ◊ ALPHA       = appha                               [Reality]
    ◊ AMOR_ALPHA = will amora                           [Reality]
    ◊ AMOR_BETA   = amorb                               [Reality]
    ◊ AMOR_HYST   = amorh                               [Reality]
)
```

3 Order DEFI_MATER_GC

3.1 Objective of the order

The order DEFI_MATER_GC aims to simplify the entry of the coefficients materials for an application to the civil engineer, with the following laws:

- concrete law MAZARS,
- steel law ECRO_LINE,
- law ENDO_FISS_EXP.

In this order, the physical properties are informed (elastic, yield stress coefficients, characteristic resistances,…), at exit one lays out of a concept "material", which one can then assign to the various meshs with the order AFFE_MATERIAU.

3.2 Operand INFORMATION

Allows to have, in the file of message, the echo of the order DEFI_MATERIAU used by DEFI_MATER_GC at the time of the definition of material.

The order DEFI_MATER_GC always print the parameters of material which are transmitted to the order DEFI_MATERIAU (confer the paragraph "example of use").

3.3 Other operands

Operands RHO, ALPHA, AMOR_ALPHA, AMOR_BETA, AMOR_HYST correspond and have the same meaning as those which one finds under the key word factor ELAS order DEFI_MATERIAU [U4.43.01].

4 Key word factor MAZARS

The model of behavior of Mazars is an elastic model of behavior endommageable making it possible to describe the softening behavior of the concrete. It distinguishes behaviour in traction and compression.

4.1 Operand CODING

The order DEFI_MATER_GC can use code of practice or advices resulting from codings to determine the parameters of the law of behavior MAZARS.

♦ CODING = 'BAEL91'|' EC2'|' ESSAI'

- 'BAEL91' : indicate that the parameters used in the definition of materials result from coding BAEL 1991.
- 'EC2' : indicate that the parameters used in the definition of materials result from coding EUROCODE 2.
- 'TEST' : indicate that the parameters used in the definition of materials come from test.

For example, according to BAEL 1991, for the material concrete knowing its characteristic resistance in compression FCJ, its resistance in traction can be estimated by: $FTJ=0.6+0.06\,FCJ$ where FTJ and FCJ are in MPa.

4.1.1 Case where CODIFICATION=' BAEL91'

The parameters used in the definition of materials result from coding BAEL 1991.
♦ UNITE_CONTRAINTE
Unit of constraint of the problem [MPa | Pa]: Méga-Pascal or Pascal. The seizure of this operand is obligatory, because the formulas used in the continuation requires to know if the parameters materials are in Pa or MPa. Lbe parameters materials which are returned by the order are in the same system of unit. UNITE_CONTRAINTE must thus be compatible with the units of the study.

- Pa : the parameters materials are homogeneous with Pa.
- MPa : parameters materials are homogeneous with MPa.

♦ FCJ
Constraint with the peak in compression, in Pa or MPa, according to the value of UNITE_CONTRAINTE.

4.1.2 Case where CODIFICATION=' EC2'

♦ UNITE_CONTRAINTE
Unit of constraint of the problem MPa or Pa : Méga-Pascal or Pascal. The seizure of this operand is obligatory, because it is necessary to turn over the parameters materials in the system of unit used to make the study.

♦ CLASS
Resistance in compression of the concrete is indicated by strength classes related to the characteristic resistance measured on cylinder or cube, in accordance with IN 206-1.
The classes available in the operator are all those defined in EUROCODE 2 :

'C12/15' 'C16/20' 'C20/25' 'C25/30' 'C30/37' 'C35/45' 'C40/50'
'C45/55' 'C50/60' 'C55/67' 'C60/75' 'C70/85' 'C80/95' 'C90/105'

4.1.3 Case where CODIFICATION=' ESSAI'

In this case, the user must inform all the characteristics necessary to determine the parameters of the law of behavior of MAZARS. The user must give these characteristics in a system of units compatible with his study.

Obligatory parameters:

- ♦ FCJ : Constraint with the peak in compression.
- ♦ EIJ : Young modulus.
- ♦ EPSI_C : Deformation with the peak in compression.
- ♦ FTJ : Constraint with the peak in traction.

Optional parameters, presented in the table 4.1.3-a, are those which one finds under the key word factor MAZARS order DEFI_MATERIAU [U4.43.01].

EPSD0	Threshold of damage in deformation
AC , B C	Coefficients allowing to fix the pace of the curved post-peak in compression.
AT , B T	Coefficients allowing to fix the pace of the curved post-peak in traction.
K	Parameter of correction for shearing.

Table 4.1.3-a : Parameters materials of law MAZARS.

- ◊ NAKED : Poisson's ratio.
- ◊ SIGM_LIM : Ultimate stress.
- ◊ EPSI_LIM : Limiting deformation.

4.2 Operation

4.2.1 Parameters of the law MAZARS

The parameters of the law are given using the following characteristics: FCJ, EIJ, EPSI_C, FTJ. The formulas are:

$$\varepsilon_0 = f_{tj}/E_{ij} \quad \beta = 1.10 \quad B_T = E_{ij}/f_{tj} \quad A_T = 0.70$$

$$B_c = \frac{1}{\varepsilon_c \nu\sqrt{2}} \quad A_c = \frac{\left(\frac{f_{cj}\nu\sqrt{2}}{E_{ij}} - \varepsilon_0\right)}{\varepsilon_c \nu\sqrt{2}\,\%exp\left(B_c\left(\varepsilon_0 - \varepsilon_c\nu\sqrt{2}\right)\right) - \varepsilon_0}$$

$$\sigma_{ELS} = 0.6\, f_{cj} \quad \varepsilon_{ELU} = 3.5‰$$

A_c and B_c are given by solving the equations resulting from the writing 1D behavior of MAZARS in order to respect the constraint and the deformation with the peak, as well as the horizontal tangent with the peak.

- B_c is obtained while solving $f'(\varepsilon_c) = 0$
- A_c while solving $f_{cj} = f(\varepsilon_c)$.

4.2.2 In the case BAEL 1991

Two operands are obligatory: UNITE_CONTAINTE, FCJ.
The order determines the sizes necessary by formulas or rules resulting from BAEL91. In the formulas below Lbe sizes f_{cj}, f_{tj}, E_{ij} are in MPa .

$$E_{ij} = 11000.0\sqrt[3]{f_{cj}} \quad f_{tj} = 0.6 + 0.06\, f_{cj} \quad \varepsilon_c = 0.620\text{E-}3\sqrt[3]{f_{cj}} \quad \nu = 0.200$$

Parameters of the law of MAZARS are then given.

4.2.3 In the case EUROCODE 2

Two operands are obligatory: UNITE_CONTAINTE, CLASS.
The order determines the sizes necessary by formulas or rules resulting from EUROCODE 2. In the formulas below Lbe sizes $f_{ck}, f_{cm}, f_{ctm}, E_{cm}$ are in *MPa.*

f_{ck} : characteristic resistance in compression measured on cylinder to 28 days.

f_{cm} : average resistance in compression of the concrete to 28 days.

$$f_{cm} = f_{ck} + 8.0$$

f_{ctm} : average resistance in traction of the concrete.

$$f_{ctm} = \begin{cases} 0.30 \ f_{ck}^{2/3} & \textit{pour classe} \leq \mathrm{C50/60} \\ 2.12 \ \log(1 + f_{cm}/10) & \textit{pour classe} > \mathrm{C50/60} \end{cases}$$

E_{cm} : tangent module

$$E_{cm} = 22.0\mathrm{E}{+}03 \left(\frac{f_{cm}}{10}\right)^{0.3}$$

ε_{c1} : deformation with the peak in ‰

$$\varepsilon_{c1} = 0.7 \ f_{cm}^{0.31} \quad \textit{toujours} \leq 2.8$$

ε_{cu1} : ultimate limiting deformation in ‰ .

$$\varepsilon_{cu1} = \begin{cases} 2.80 + 27 \left[\frac{98 - f_{cm}}{100}\right]^4 & \textit{pour classe} > \mathrm{C50/60} \\ 3.5 & \textit{pour classe} \leq \mathrm{C50/60} \end{cases}$$

Parameters of the law of MAZARS are then given.

4.2.4 In the case TEST

Four operands are obligatory : FCJ, EIJ, EPSI_C, FTJ. Parameters of the law of behavior of MAZARS are given like previously.

So operands optional presented to the table 4.1.3-a are informed, they are taken into account by the order. It is thus necessary to make sure of the coherence of the provided sizes, in particular in the following cases:

- the user gives B_c . The equation $f'(\varepsilon_c) = 0$ can not be checked, in this case the behavior will pass by the point f_{cj} but f_{cj}, ε_c will not be any more a extremum.
- the user gives A_c . The equation $f_{cj} = f(\varepsilon_c)$ can not be checked, in this case the behavior will not pass by the point f_{cj} and ε_c .

4.3 Example of use

To define a concrete which has a behavior of MAZARS with a resistance characteristic of $40.0\,MPa$ for a study whose constraints must be in *Pa* , the order is used in the following way:

```
BETONM = DEFI_MATER_GC (
   MAZARS = _F (FCJ=40.0E+06, UNITE_CONTRAINTE = "Phas",),
)
```

The order prints in the file of message all the values which are used to define material.

```
== PARAMÈTRES OF LAW MAZARS [PA] ==
ELASTICITY PART:
  E =  3.76194246E+10, NAKED =  2.00000000E-01,
NON-LINEAR PART:
  BT =  1.25398082E+04, K =  0.70000000E+00,
  AT =  7.00000000E-01, EPSI_LIM =  3.50000000E-03,
  BC =  1.66741558E+03, SIGM_LIM =  2.40000000E+07,
  AC =  1.28292129E+00, EPSD0 =  7.97460364E-05,
FOR INFORMATION:
 FCJ =  4.000E+07, FTJ =  3.0000E+06, EPSI_C =  2.12036757E-03,
```

The table 4.3-a give sets of parameters obtained with the rules previously described.

Fcj [MPa]	30,0	35,0	40,0	45,0	50,0
Ftj [MPa]	2,4	2,7	3,0	3,3	3,6
$Young$ [MPa]	34180,0	35982,0	37619,0	39126,0	40524,0
Nu	0,2	0,2	0,2	0,2	0,2
$Epsi_c$	1,93E-03	2,03E-03	2,12E-03	2,21E-03	2,28E-03
At	0,7	0,7	0,7	0,7	0,7
Bt	14241,0	13327,0	125 39. 8	11856,0	11257,0
$Epsi0$	7,02E-05	7,50E-05	7.9 7 E-05	8,43E-05	8,88E-05
Bc	1835,2	1743,3	1667,4	1603,2	1547,9
Ac	1,128	1,209	1,283	1,351	1,415

Table 4.3-a : Parameters for the law MAZARS.

The figure 4.3-a present the various curves of compression obtained with the values of the table 4.3-a.

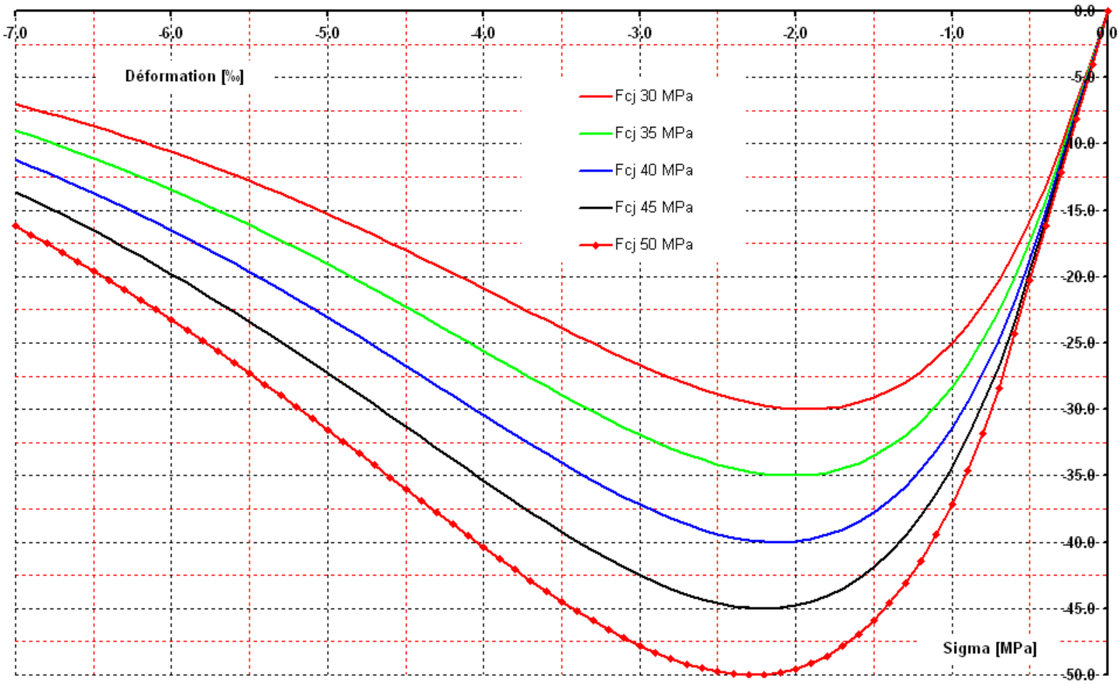

Figure 4.3-a : Law of MAZARS curves of compression $\sigma=f(\varepsilon)$ **.**

5 Key word factor STEEL

The model of behavior is elastoplastic with a linear kinematic work hardening.

5.1 Operands

Operands are those which one finds under words keys factors ELAS and ECRO_LINE order DEFI_MATERIAU [U4.43.01].

♦ E : Young, elastic slope modulus of the curve $\sigma=f(\varepsilon)$

♦ SY : Elastic limit.

◊ NAKED : Poisson's ratio

◊ D_SIGM_EPSI : Slope of work hardening on the curve $\sigma=f(\varepsilon)$. (cf . ECRO_LINE order DEFI_MATERIAU).

◊ SIGM_LIM : Ultimate stress.

◊ EPSI_LIM : Limiting deformation.

5.2 Operation

Two operands are obligatory: E, SY. So operands optional are indicated, they are taken into account by the order and the values will not be modified. It is thus necessary to make sure of the coherence of the provided sizes.

If operands optional are not indicated, the order determines them missing sizes by the following formulas:

$\nu=0.3 \quad dsde=E/10000.0 \quad \sigma_{ELS}=\sigma_y/1.1 \quad \varepsilon_{ELU}=10.0‰$

5.3 Examples of use

To define a steel with a yield stress of $400.0 MPa$, the order is used in the following way:

```
STEEL = DEFI_MATER_GC (
   STEEL =_F (E=2.0E+11, SY=400.0E+06,),
)
```

The order prints in the file of message all the values which are used to define material.

```
== PARAMÈTRES OF LAW ECRO_LINE ==
ELASTICITY PART:
   E =  2.000E+11, NAKED =  3.00000000E-01,
NON-LINEAR PART:
   SY =  4.00000000E+08, EPSI_LIM =  1.00000000E-02,
   D_SIGM_EPSI =  2.00000000E+07, SIGM_LIM =  3.63636364E+08,
FOR INFORMATION:
   EPSI_ELAS =  2.00000000E-03,
```

6 Key word factor ENDO_FISS_EXP

The model of behavior ENDO_FISS_EXP of behavior endommageable is an elastic model not room (available in modeling GRAD_VARI). It makes it possible to describe the softening behavior of the concrete. It distinguishes in particular behaviour in traction and compression and described well the states from shearing or bi--traction. When the characteristic length tends towards zero, it approaches a cohesive model, which explains why one informs parameters characteristic of a cohesive law more than of a voluminal model of damage.

6.1 Operands

E	Young modulus (Pa)
NAKED	Poisson's ratio
FT	Threshold of damage in simple traction (Pa)
FT_FENDAGE	Threshold of damage as identified by a test of splitting (Pa)
FC	Threshold of damage in compression (Pa)
GF	Energy of cracking (N/m)
P	Parameter of principal work hardening of the asymptotic cohesive law
DSIG_DU	Initial slope of work hardening of the asymptotic cohesive law
Q	Secondary parameter of work hardening of the asymptotic cohesive law
Q_REL	Secondary parameter of work hardening (ranging between 0 and 1)
LARG_BANDE	Bandwidth of localization - m)
COEF_RIGI_MINI	Threshold of swing to the secant tangent matrix

Table 6.1-a : Parameters materials of law ENDO_FISS_EXP

6.2 Operation

Certain characteristics do not require complementary explanations: the Young modulus, the Poisson's ratio, thresholds of damage in traction and compression, the energy of cracking. They are usual characteristics for the modeling of the damage of the concrete. In alternative to FT, one also proposes to inform directly FT_FENDAGE, because identification of a test of splitting (or cylinder splitting test) led to one FT higher by 10% with FT_FENDAGE.

Concerning the parameters P and Q who characterize the standardized answer of the asymptotic cohesive model (the constraint is standardized by FT, the opening by GF/FT), one places at the disposal several manners to inform them. One can directly inform P (higher than 1) or the effect of P on the initial slope of the cohesive answer, i.e the derivative of the constraint compared to the jump of displacement when the cohesive zone starts to open: this slope is negative but one introduces his absolute value via the keyword DSIG_DU. This way, one can more easily establish the link with certain cohesive models of the literature (typically, bilinear laws). For Q, one can directly inform his value (worthless by default) but this one is obligation to remain between 0 and one value maximum which depends on P. to simplify the data of Q, one gives the opportunity of informing Q into relative compared to this maximum value via the keyword Q_REL.

One introduces finally the bandwidth of localization which is supposed to reflect a cohesive crack. It is the double of the parameter D (which measures him to it half-width of band in 1D, as described in the theoretical reference of the model).

As for the parameter COEF_RIGI_MINI, it is that introduced into DEFI_MATERIAU [U4.43.01]. When the residual rigidity standardized by E is lower than COEF_RIGI_MINI, one substitutes for the tangent matrix the secant matrix corresponding to this rigidity, which limits the problems involved in possible completely destroyed zones (i.e without residual rigidity). This parameter is without incidence on the physique of the model, it intervenes only on the properties of convergence of the algorithm of Newton. By default, this function is not activated (COEF_RIGI_MINI = 0), which seems very well to be appropriate in most case.

In a general way, one returns to the reference material of the model [R5.03.25] for more detailed explanations on the significance of the various parameters of the model.