# Operator CALC_FERRAILLAGE

## 1 Goal

To calculate the densities of reinforcement in elements hulls and plates according to the requests: generalized efforts, obtained beforehand by the option EFGE_ELNO.

The order enriches the structure of data of the type result, provided under the keyword RESULT, of a field of size reinforcement, of which the components are described in this document.

# 2 Syntax

```
resu [*] = CALC_FERRAILLAGE    (

        ♦ reuse         =  resu
        ♦ RESULTAT      =  resu            [evol_elas, evol_noli, dyna_trans]
        ♦ CODING    =  /   'EC2',                              [DEFECT]
                       /   ' BAEL91 ',
        ♦ TYPE_COMB     =  /   'ELS',
                           /   'ELECTED',

#       Selection of the sequence number:
       /  TOUT_ORDRE    =      'YES',
       /  NUME_ORDRE    =      l_nuor ,                              [l_I]
       /  LIST_ORDRE    =      l_nuor ,                              [listis]
       /  ♦   /  INST    =     l_inst ,                              [l_R]
              /  LIST_INST    =  / l_inst,                          [listr8]
              /  FREQ         =  / l_inst,                          [listr8]
              /  LIST_ FREQ   =  / l_freq,                          [listr8]
          ◊   |  PRECISION    =  / prec,                            [R]
                                 / 1.0E-6,                          [DEFECT]
              |  CRITERION       =  / 'RELATIVE',                      [DEFECT]
                                 / 'ABSOLUTE',

#      if CODING = 'BAEL91'
        ♦ AFFE   =  _F (   ♦/ALL     =/'YES'
                                    / 'NOT'
                             /GROUP_MA  = l_grma,                   [l_gr_maille]
                           ♦ C_SUP      = enrobS,                  [R]
                           ♦ C_INF      = enrobS,                  [R]
                           ◊ NR           = N,                        [R]
                           ◊ FE         = sigaci,                  [R]
                           ◊ FCJ        = sigbet,                  [R]
                           ◊ GAMMA_S    = gs,                      [R]
                           ◊ GAMMA_C    = Ge                       [R]
                           ◊ ALPHA_CC   =/ 0.85,                   [DEFECT]
                                        / alphacc,                 [R]
                           ◊ S IGS_ELS  = sigaci,                  [R]
                           ◊ SIGC_ELS   = sigbet,                  [R]
                            ◊ RHO _ STEEL   =/- 1,                  [DEFECT]
                                        / rhoaciert,               [R]
#                           if RHO_ACIER = 0,
                                  ◊ ALPHA_REINF   =/1,              [DEFECT]
                                                  / areinf,        [ R ]
                                  ◊ ALPHA_SHEAR     =/1,              [DEFECT]
                                                  / has shear,         [R]
                                  ◊ ALPHA_STIRRUPS  =/1,              [DEFECT]
                                                  / has stirr,         [R]
                                  ◊ RHO _ CRIT    =/1 50,           [DEFECT]
                                                  / rhocrit,       [R]
                                  ◊ DNSTRA _ CRIT    =/ 0.006            [DEFECT]
                                                  / datcrit,       [R]
                                  ◊ L _ CRIT         =/ 1,             [DEFECT]
                                                  / lcrit,         [R]
                      )
```

```
#      if CODING = 'EC2'
         ♦ AFFE   =   _F (   ♦/ALL     =/'YES'
                                       / 'NOT'
                             /GROUP_MA   = l_grma,                [l_gr_maille]
                           ♦ C_SUP         = enrobS,              [R]
                           ♦ C_INF         = enrobS,              [R]
                           ◊ NR              = N,                    [R]
                           ◊ FCK           = sigaci,              [R]
                           ◊ FYK           = sigbet,              [R]
                           ◊ SIGC_ELS      = sigaciL,             [R]
                           ◊ SIGS_ELS      = sigbetL,             [R]
                           ◊ GAMMA_S       = gs,                  [R]
                           ◊ GAMMA_C       = GC                   [R]
                           ◊ ALPHA_E       = alphaE               [R]
                           ◊ CLASSE_ACIER  =/'A',
                                             / 'B',               [DEFECT]
                                             / 'C',
                           ◊ ALPHA_CC      =/ 1.0                 [DEFECT]
                                             / alphacc,           [R]
                            ◊ RHO _ STEEL     =/- 1,              [DEFECT]
                                             / rhoaciert,            [R]
#                           if RHO_ACIER = 0,
                                  ◊ ALPHA_REINF   =/1.            [DEFECT]
                                                   / areinf,      [ R ]
                                  ◊ ALPHA_SHEAR     =/1.             [DEFECT]
                                                   / has shear,       [R]
                                  ◊ ALPHA_STIRRUPS  =/1.             [DEFECT]
                                                   / has stirr,       [R]
                                  ◊ RHO _ CRIT    =/1 50 .           [DEFECT]
                                                   / rhocrit,     [R]
                                  ◊ DNSTRA _ CRIT    =/ 0.006           [DEFECT]
                                                   / datcrit,     [R]
                                  ◊ L _ CRIT         =/ 1.           [DEFECT]
                                                   / lcrit,           [R]
                              ),
         );
```

# 3 Operands

## 3.1 Operand RESULT

♦ RESULTAT = resu

Name of a concept result of the type result. It is necessarily réentrant.

## 3.2 Operand CODING

♦ CODING = / 'BAEL91'
/ 'EC2'

L E keyword CODING allows to choose the regulation used for the calculation of reinforcement. Currently the réglementatiosn available are the BAEL91 and Eurocode 2.

## 3.3 Operand TYPE_COMB

♦ / 'ELS'

Reinforcement is parameterized for a calculation in Absolute limit of Service.

/ 'ELECTED'

Reinforcement is parameterized for a calculation in Ultimate Absolute limit.

**Note:**

For the combinations of efforts, weightings are to be carried out before the call to the module CALC_FERRAILAGE. With this intention, it is necessary to extract the field from the generalized efforts, beforehand obtained by the option EFGE_ELNO, by using the function CREA_CHAMP (operation EXTR) described in the document [U4.72.04].

```
MECA1=CALC_CHAMP (reuse =MECA1,
                  RESULTAT=MECA1,
                  CONTRAINTE=' EFGE_ELNO',);
EFFORTS1=CRÉA_CHAMP (TYPE_CHAM=' ELNO_SIEF_R',
                     OPERATION=' EXTR',
                     RESULTAT=MECA1,
                     NOM_CHAM=' EFGE_ELNO',);
```

Then, by re-using the function CREA_CHAMP (operation ADZE), one can add the fields extracted by balancing them by the desired coefficient.

```
PONDERE1=CRÉA_CHAMP (TYPE_CHAM=' ELNO_SIEF_R',
                     OPERATION=' ASSE',
                     MODELE=MODELE,
                     ASSE=_F (GROUP_MA=' BALCON',
                              CHAM_GD=EFFORTS1,
                              CUMUL=' OUI',
                              COEF_R=1.35,),);
```

Lastly, to be able to use the field of efforts balanced created in CALC_FERRAILLAGE, it should be transformed into a concept result of type result thanks to the function CREA_RESU described in the document [U4.44.12].

```
PONDER=CRÉA_RESU (OPERATION=' AFFE',
                  TYPE_RESU=' EVOL_ELAS',
                  NOM_CHAM=' EFGE_ELNO',
                  AFFE= (_F (CHAM_GD=PONDERE1,
                             MODELE=MODELE,
                             CHAM_MATER=MATE,
                             CARA_ELEM=CARA,
                             INST=1.0,),),)
```

## 3.4 Selection of the sequence numbers

Use of the keywords TOUT_ORDRE, NUME_ORDRE, INST is described in the document [U4.71.00].

## 3.5 Operand AFFE

### 3.5.1 Selection of the meshs concerned with calculation

Keywords ALL and GROUP_MA allow the user to choose the meshs on which it wishes to do his elementary calculations of postprocessing.

/ ALL = 'YES'

All the meshs (carrying finite elements) will be treated. It is the value by default.

/ GROUP_MA = l_grma

Only meshs included in l_grma will be treated.

**Notice** : If the model is not solely formed by elements of hull (3D, beams,…), the keyword should not be used TOUT=' OUI'. It is necessary to indicate the elements of hull to the assistance DU keyword GROUP_MA.

### 3.5.2 Keyword specific to the option CODING = 'BAEL91'

#### 3.5.2.1 Operand C_SUP

♦ C_SUP = csup, [R]

Distance enters the concrete surface and the axis of the reinforcements of reinforcement for the higher face of the hull

**Note:**

The value of coating can be approximated to $0.1h$ with $h$ the thickness of the section.

#### 3.5.2.2 Operand C_INF

♦ C_INF = cinf, [R]

Distance enters the concrete surface and the axis of the reinforcements of reinforcement for the higher face of the hull

**Note:**

The value of coating can be approximated to $0.1h$ with $h$ the thickness of the section.

#### 3.5.2.3 Operand NR

◊ NR = N, [R]

Coefficient of equivalence steel/concrete (report of the Young moduli) (obligatory for calculation with Absolute limit of Service, ELS)

**Note:**

The value usually used is $N=15$ .

#### 3.5.2.4 Operand RHO_ACIER

◊ RHO_ACIER = rhoacier, [R]

Value of the voluminal density of steels.

#### 3.5.2.5 Operand SIGS_ELS/SIGC_ELS

◊ SIGS_ELS = sigaci

Working stress in steel (obligatory for calculation with the Absolute limit of Service) . I L is recommended in the BAEL91, to use $\mathrm{SIGS\_ELS}=0.8 f_e$ , has vec $f_e$ elastic limit of steel.

◊ SIGC_ELS = sigbet

Working stress of compression in the concrete (obligatory for calculation with the Absolute limit of Service) . It is recommended in the BAEL91, to use $\mathrm{SIGC\_ELS}=0.6 f_{cj}$ has vec $f_{cj}$ resistance characteristic of the concrete to compression.

#### 3.5.2.6 Operands FE / FCJ

◊ FE = Fe, [R]

Llimit elastic of steel has (constraint)

◊ FCJ = fcj, [R]

Resistance characteristic of the concrete to compression (forced).

#### 3.5.2.7 Operands GAMMA_S / GAMMA_C

◊ GAMMA_S = gammas , [R]

Coefficient of security on the resistance of steel with the ELECTED OFFICIAL .
In general, $\gamma_s=1.15$ for accidental combinations if not $\gamma_s=1$ .

◊ GAMMA_C = gammac, [R]

Safety coefficient on the resistance of the concrete to the ELECTED OFFICIAL.
In general, $\gamma_c=1.15$ for accidental combinations if not $\gamma_c=1.5$

#### 3.5.2.8 Operand ALPHA_DC

◊ ALPHA_CC = alphacc, [R]

Coefficient affecting the ultimate resistance of the concrete (with ELECTED OFFICIAL). It is worth 0.85 by defaults

#### 3.5.2.9 OperandS ALPHA_REINF, ALPHA_SHEAR, ALPHA_STIRRUPS, RHO_CRIT, DNSTRA_CRIT and L_CRIT

The following keywords are to be defined only if RHO_ACIER is higher than 0. They are used to calculate an indicator of complexity aiming at translating the difficulty of implementation of reinforcement on ground.

$$I_{c,i}=\frac{\alpha_{reinf}\cdot\frac{\rho_i}{\rho_{critic}}+\alpha_{shear}\cdot\frac{A_{sw,i}}{A_{sw,critic}}+\alpha_{stirrups}\cdot\frac{A_{sw,i}}{A_{sw,critic}}\cdot\frac{h_{eff,i}}{l_{crit}}}{\alpha_{reinf}+\alpha_{shear}+\alpha_{stirrups}}$$

where: $\rho_i$ is the total voluminal density of steel for element I;
$A_{sw,i}$ is the density of steel of shearing action for element I;
$h_{eff,i}=h-c-c'$ is the effective height considered for element I;

◊ ALPHA_REINF = / 1, [DEFECT]
/ areinf , [R]

Weighting coefficient of the ration of density of steel per cubic meter of concrete.

◊ ALPHA_SHEAR = / 1, [DEFECT]

```
                    / has shear ,    [R]
```

Weighting coefficient of the ration of density of steel of shearing action.

```
◊ ALPHA_STIRRUPS = / 1,          [DEFECT]
                   / has stirr ,    [R]
```

Weighting coefficient of the ration length of the steel pins of shearing action.

```
◊ RHO_CRIT =/ 150,               [DEFECT]
            / rhocrit ,          [R]
```

Voluminal density of critical reinforcement.

```
◊ DNSTRA_CRIT = / 0,006,         [DEFECT]
                / rhocrit ,      [R]
```

Density of reinforcement of shearing action critical.

```
◊ L_CRIT =  / 1,                 [DEFECT]
            / rhocrit ,          [R]
```

Length criticizes steel pins of shearing action.

### 3.5.3 Keyword specific to the option CODING = 'EC2'

#### 3.5.3.1 Operand C_SUP

```
♦ C_SUP = csup,        [R]
```

Distance enters the concrete surface and the axis of the reinforcements of reinforcement for the higher face of the hull

**Note:**
The value of coating can be approximated to $0.1h$ with $h$ the thickness of the section.

#### 3.5.3.2 Operand C_INF

```
♦ C_INF = cinf,        [R]
```

Distance enters the concrete surface and the axis of the reinforcements of reinforcement for the higher face of the hull

**Note:**
The value of coating can be approximated to $0.1h$ with $h$ the thickness of the section.

#### 3.5.3.3 Operand ALPHA_E

```
◊ ALPHA_E = N,          [R]
```

Coefficient of equivalence steel/concrete (report of the Young moduli) (obligatory for calculation with Absolute limit of Service, ELS)

**Note:**
The value usually used is $\alpha_e = 15$.

#### 3.5.3.4 Operand RHO_ACIER

```
◊ RHO_ACIER = rhoacier,      [R]
```

Value of the voluminal density of steels.

#### 3.5.3.5 Operand SIGS_ELS/SIGC_ELS

◊ SIGS_ELS = sigaci

Working stress in steel (obligatory for calculation with the Absolute limit of Service).
It is recommended inEC2 , to use $SIGS\_ELS=0.8 f_{yk}$ , hasvec $f_{yk}$ elastic limit steel.

◊ SIGC_ELS = sigbet

Working stress of compression in the concrete (obligatory for calculation with the Absolute limit of Service).
It is recommended inEC2, to use $SIGC\_ELS=0.6 f_{ck}$ hasvec $f_{ck}$ resistance characteristic of the concrete to compression.

#### 3.5.3.6 Operands FYK/FCK

◊ FYK = F yk , [R]

elastic limit of steel (constraint)

◊ FCK = FCK, [R]

resistance characteristic of the concrete to compression (forced).

#### 3.5.3.7 Operands GAMMA_S / GAMMA_C

◊ GAMMA_S = gammas , [R]

Coefficient of security on the resistance of steel with the ELECTED OFFICIAL .
In general, $\gamma_s=1.5$ for accidental combinations if not $\gamma_s=1.15$ .

◊ GAMMA_C = gammac, [R]

safety coefficient on the resistance of the concrete to the ELECTED OFFICIAL.
In general, $\gamma_c=1.2$ for accidental combinations if not $\gamma_c=1.5$

#### 3.5.3.8 Operand UTIL_COMPR

◊ UTIL_COMPR = / 'NOT', [DEFECT]
/ 'YES',

Taking into account of compression in the calculation of steels of shearing action with the ELS.

#### 3.5.3.9 Operands CLASSE_ACIER

◊ CLASSE_ACIER = class , [R]

Cweary steel. Must be one of the three values: 'With' with normal ductility, 'B' with high ductility or 'It with very high ductility. It makes it possible to define the value of pivot A $PIV_A=2,5\%$ , $PIV_A=5\%$ or $PIV_A=7,5\%$ . The steel by default class is the class B.

#### 3.5.3.10 Operand ALPHA_DC

◊ ALPHA_CC = alphacc, [R]

Coefficient affecting the ultimate resistance of the concrete (with ELECTED OFFICIAL). It is worth 1 by default in the EC2

#### 3.5.3.11 OperandS ALPHA_REINF, ALPHA_SHEAR, ALPHA_STIRRUPS, RHO_CRIT, DNSTRA_CRIT and L_CRIT

The following keywords are to be defined only if RHO_ACIER is higher than 0. They are used to calculate an indicator of complexity aiming at translating the difficulty of implementation of reinforcement on ground.

$$I_{c,i}=\frac{\alpha_{reinf}\cdot\frac{\rho_i}{\rho_{critic}}+\alpha_{shear}\cdot\frac{A_{sw,i}}{A_{sw,critic}}+\alpha_{stirrups}\cdot\frac{A_{sw,i}}{A_{sw,critic}}\cdot\frac{h_{eff,i}}{l_{crit}}}{\alpha_{reinf}+\alpha_{shear}+\alpha_{stirrups}}$$

where: $\rho_i$ is the total voluminal density of steel for element I;
$A_{sw,i}$ is the density of steel of shearing action for element I;
$h_{eff,i}=h-c-c'$ is the effective height considered for element I;

◊ ALPHA_REINF = / 1, [DEFECT]
/ areinf , [R]

Weighting coefficient of the ration of density of steel per cubic meter of concrete.

◊ ALPHA_SHEAR = / 1, [DEFECT]
/ has shear , [R]

Weighting coefficient of the ration of density of steel of shearing action.

◊ ALPHA_STIRRUPS = / 1, [DEFECT]
/ has stirr , [R]

Weighting coefficient of the ration length of the steel pins of shearing action.

◊ RHO_CRIT =/ 150, [DEFECT]
/ rhocrit , [R]

Voluminal density of critical reinforcement.

◊ DNSTRA_CRIT = / 0,006, [DEFECT]
/ rhocrit , [R]

Density of reinforcement of shearing action critical.

◊ L_CRIT = / 1, [DEFECT]
/ rhocrit , [R]

Length criticizes steel pins of shearing action.

# 4 Composition of the produced field

The result is enriched by a new field (named 'REINFORCEMENT'in the structure of data) whose components are:

- a density of longitudinal reinforcement in the direction $X$ element for the lower face of the element ( $DNSXI$ ) ;
- the equivalent for the higher face ( $DNSXS$ ) ;
- a density of longitudinal reinforcement in the direction $Y$ element for the lower face of the element ( $DNSYI$ ) ;
- the equivalent for the higher face ( $DNSYS$ ) ;
- density of transverse reinforcement ( $DNST$ ) ;
- total voluminal density of steel ( $DNSVOL$ );
- an indicator of complexity of implementation reinforcement ( $CONSTRUC$ ).

The densities of reinforcement are calculated according to the method of CAPRA and MAURY [R7.04.05]. These densities are expressed in unit of surface by linear length of hull. For example, if the grid is in meters (with data of characteristics elementary and material in coherence), the densities will be expressed in $m^2/m$ for steels of inflection and in $m^2/m^2$ for steels of shearing action.

The field of reinforcement is calculated for every moment specified by the user (by default: all). If one wants to calculate the field containing the values "max" during the transient, one can carry out the order:

```
FERMAX=CRÉA_CHAMP (  OPERATION=' EXTR', TYPE_CHAM=' ELEM_FER2_R',
                     NOM_CHAM=' FERRAILLAGE', RESULTAT=Solution,
                     TYPE_MAXI=' MAXI_ABS', TYPE_RESU=' VALE',
                        )
```

# 5 Errors and alarms

## 5.1 Errors caused by an inconsistency of the parameters of entry

A checking of the coherence of the parameters of entry is carried out at the beginning of the execution of the order CALC_FERRAILLAGE. Calculation can be stopped by a fatal error in the following cases:

- in the case BAEL91 with the ELECTED OFFICIAL: if keywords GAMMA_S, GAMMA_C, FE or FCJ, are not well informed;
- in the case BAEL91 with the ELS: if keywords NR, SIGS_ELS or SIGC_ELS are not well informed;
- in the case EC2 with the ELECTED OFFICIAL: if keywords GAMMA_S, GAMMA_C FYK or FCK, are not well informed;
- in the case EC2 with the ELS: if keywords ALPHA_E, SIGS_ELS, SIGC_ELS or FCK are not well informed;
- for all the cases: if the value of coating is higher than the thickness of the element of structure.

## 5.2 Alarms emitted during calculation with the ELECTED OFFICIAL steels of inflection

Calculation with the ELECTED OFFICIAL steels of inflection can to emit one or more alarms in the following cases :

- so at least a facet is out of pivot B too compressed: in this case calculation on the other facets of the element of structure is ignored and the density of reinforcement is fixed at -1 for the element;
- so at least a facet is out of pivot C alone (without being too compressed) and that no other facet is out of pivot C too compressed: in this case the density of reinforcement is fixed at -1 for the element;
- so at least a facet is out of pivot C too compressed: in this case calculation on the other facets of the element of structure is ignored and the density of reinforcement is fixed at -1 for the element;

## 5.3 Alarms emitted during calculation with the ELECTED OFFICIAL transverse steels

Calculation with the ELECTED OFFICIAL transverse steels can to emit one or more alarms in the following cases :

- if the concrete is sheared too much: in this case the density of reinforcement of transverse steels is fixed at -1.

## 5.4 Alarms emitted during calculation with the ELS steels of inflection

Calculation with the ELECTED OFFICIAL steels of inflection can to emit one or more alarms in the following cases :

- so at least a facet is out of pivot B too compressed: in this case calculation on the other facets of the element of structure is ignored and the density of reinforcement is fixed at -1 for the element;
- so at least a facet is out of pivot C alone (without being too compressed) and that no other facet is out of pivot C too compressed: in this case the density of reinforcement is fixed at -1 for the element;
- so at least a facet is out of pivot C too compressed: in this case calculation on the other facets of the element of structure is ignored and the density of reinforcement is fixed at -1 for the element;

## 5.5 Error emitted during calculation with the ELS steels of inflection

A fatal error is emitted during the calculation of steels of inflection to the ELS if the compressive stress of the concrete exceeds its maximum value (definite by SIGC_ELS ( BAEL91 or EC2 ).

## 5.6 Case for which the density of reinforcement is fixed at -1

In case following, the density of reinforcement turned over not Aster is -1:

- with the ELECTED OFFICIAL: so at least a facet is out of pivot B too compressed
- with the ELECTED OFFICIAL: so at least a facet is out of pivot C or pivot C too compressed

- with the ELECTED OFFICIAL calculation of transverse steels: if the concrete is sheared too much on at least a facet
- with the ELS: so at least a facet is out of pivot B too compressed
- with the ELS: so at least a facet is out of pivot C or pivot C too compressed

# 6 Examples of use

See the cases tests ssls126c, ssls134a ,ssls134B, ssls134c, ssls135a and SSLx100c.