

Operator COMBINAISON_FERRAILLAGE

1 Goal

The goal of this operator is to calculate densities of reinforcement in elements hulls and plates according to the requests for several combinations of loading.

As starter, this macro-order takes a multiple result of type `mult_elas`. Each result of `mult_elas` contains the generalized efforts, obtained beforehand by the option `EFGE_ELNO`.

The order enriches each result of `mult_elas` of a field of size reinforcement, in calling several times the order `CALC_FERRAILLAGE`.

Also, the order adds `results` with the structure of data `mult_elas`.

2 Syntax

```
resu = COMBINAISON_FERRAILLAGE (

  ♦ reuse          = resu
  ♦ RESULT         = resu                                [multi_elas]
  ♦ CODING = / 'EC2',                                  [DEFECT]
              / 'USER',

# To choose at least a kind of checking for a list of nom_cas
  ♦ COMBINATION = _F (
    ♦ STANDARD = / 'ELS_CHARACTERISTIQUE',
                / 'ELU_FONDAMENTAL',
                / 'ELU_ACCIDENTEL',

    ♦ / NOM_CAS = l_nomcas                                [l_K]
      / NUME_ORDRE = l_numeorde,                          [l_I]
  )

# if CODING = 'EC2'
  ♦ AFFE = _F (
    ♦/ ALL          = 'YES'
      / GROUP_MA    = l_grma,                             [l_gr_maille]
    ♦ TYPE_STRUCTURE = '2D'
    ♦ C_SUP          = enrobs,                             [R]
    ♦ C_INF          = enrobs,                             [R]
    ◇ FCK           = sigaci,                             [R]
    ◇ FYK           = sigbet,                             [R]
    ◇ SIGC_ELS      = sigacil,                             [R]
    ◇ SIGS_ELS      = sigbetl,                             [R]
    ◇ GAMMA_S_BOTTOM = gs,                                 [R]
    ◇ GAMMA_S_ACCI  = gs,                                 [R]
    ◇ GAMMA_C_BOTTOM = gc,                                 [R]
    ◇ GAMMA_C_ACCI  = gc,                                 [R]
    ◇ ALPHA_E       = alphae,                             [R]
    ◇ CLASSE_ACIER  =/'with'
                    /'B'                                 [DEFECT]
                    /'C'
    ◇ ALPHA_CC      = /1.0                                 [DEFECT]
                    /alphacc                             [R]
    ◇ E_S          = be                                   [R]
  )
)
```

3 Operands

3.1 Operand RESULT

◆ RESULT = resu

Name of a concept result of the type `mult_elas`. It is necessarily D-entering.

3.2 Operand CODING

◆ CODING =/ 'EC2', [DEFECT]
/ 'UTILISATEUR',

It is coding to be used for the checks.: Eurocode 2 (EC2) or defined by the user)

3.3 Operand COMBINATION

◆ COMBINATION = _F (◆ STANDARD =/ 'ELS_CARACTERISTIQUE',
/ 'ELU_FONDAMENTAL',
/ 'ELU_ACCIDENTEL',
◆/ NOM_CAS = l_nomcas
/NUME_ORDRE = l_numeordre,)

With this operator reference markétable one provides to the order the list of the cases (results of `mult_elas`) on which to carry out dimensioning who correspond to the checks of absolute limit of service (the characteristic combination is the only available one for the moment) and ultimate (fundamental, victim).

The choice enters `ELU_FONDAMENTAL` and `ELU_ACCIDENTEL` allows to choose the value of the safety coefficients `GAMMA` (see operand `AFPE`, § 3.4).

3.3.1 Keyword TYPE

◆ STANDARD =/ 'ELS_CARACTERISTIQUE',
/ 'ELU_FONDAMENTAL',
/ 'ELU_ACCIDENTEL',

With this keyword, one chooses the type of checking to be associated with the list of case. For the moment the options available are the fundamental ultimate limiting states or accidental and states limitingS of service characteristics such as defined by Eurocodes.

3.3.2 KeywordS NUME_ORDRE and NOM_CAS

Here the list of the well informed case is provided associated with the checkingE in `TYPE`, that is to say like lists sequence number of the cases is like lists names of the cases (label associated with each `result mult_elas`).

Notice

Here the sequence number does not indicate a moment of calculation or a frequency as for the structures of data `result` but a number of case (one of `results` contents by `multi_elas`).

3.4 Operand AFPE

One great part Dbe keyword informed here are the same ones as for the order `CALC_FERRAILLAGE`.

One will note the addition keyword `TYPE_STRUCTURE` who is used to characterize the type of structure which one wants to dimension reinforcement. It is necessary that meshes informed under `GROUP_MA` are homogeneous in terms of modeling and type of structure.

```
◆ TYPE_STRUCTURE = '2D'  
◆/ ALL           = 'YES'  
  /GROUP_MA      = l_grma
```

Another difference with the keyword of `CALC_FERRAILLAGE` consist in the choice of the safety coefficients:

```
◇ GAMMA_S_BOTTOM = gs ,           [R]  
◇ GAMMA_S_ACCI   = gs ,           [R]  
◇ GAMMA_C_BOTTOM = gc ,           [R]  
◇ GAMMA_C_ACCI   = gc ,           [R]
```

The values will be chosen informed under `GAMMA_S_BOTTOM` and `GAMMA_C_BOTTOM` to feed `CALC_FERRAILLAGE` if the user chose the option `ELU_FONDAMENTAL` operande `COMBINATION` (§3.3) for a certain case of load. For `ELU_ACCIDENTEL`, the valueS of `GAMMA_S_ACCI` and `GAMMA_C_ACCI` will be selected.

3.5 Composition of the produced field

The result of each case of name `NOM_CAS` is enriched by a new field (named 'REINFORCEMENT' in the structure of data) whose components (for elements of structure 2D) are:

- a density of longitudinal reinforcement in the direction X element for the lower face of the element (`DNSXI`) - in $\frac{m^2}{m}$;
- the equivalent for the higher face (`DNSXS`) in $\frac{m^2}{m}$;
- a density of longitudinal reinforcement in the direction Y element for the lower face of the element (`DNSYI`) - in $\frac{m^2}{m}$;
- the equivalent for the higher face (`DNSYS`) - in $\frac{m^2}{m}$;
- density of transverse reinforcement (`DNST`) - in $\frac{m^2}{m}$
- the constraint in the compressed concrete `SIGMBE` ;
- deformation in the compressed concrete `EPSIBE` .

The field of reinforcement is calculated for the only existing moment for each case. One of the principal goals of the order `COMBINAISON_FERRAILLAGE` is to calculate, for each type of reinforcement (longitudinal, transverse...), dimensioning combination, i.e. that which maximizes the type of reinforcement considered.

Thus, the algorithm of the order `COMBINAISON_FERRAILLAGE` call the order `CALC_FERRAILLAGE` for each case (sequence number of `mult_elas`) by choosing the type of checking informed by `TYPE_COMB`. Then, the densities of reinforcement (for each type of reinforcement) are compared between them, that which causes the most important reinforcement is the dimensioning combination. This comparison is made with each call of `COMBINAISON_FERRAILLAGE`, therefore on each node of the groups of meshes selected.

There will be thus as much of combinations dimensioning that types of reinforcements.

One creates in the structure given `multi_elas` two new cases:

- `COMB_DIME_ACIER` → Under this name of case is indicated the maximum reinforcements for each finite element and standard of reinforcement
- `COMB_DIME_ORDRE` → Under this name of cases is indicated the sequence number of the cases which provide the maximum reinforcements (dimensioning cases) for each finite element and standard of reinforcement.

3.6 Errors and alarms

3.6.1 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 `COMBINAISON_FERRAILLAGE`. Calculation can be stopped by a fatal error in the following cases:

- If the user asks for a calculation on beams or posts whereas the dimensioning of these elements of structure is not envisaged yet by `C ode_ has ster` (order `CALC_FERRAILLAGE`)
- If none occurrence operand `COMBINATION` or `AFFE` is informed.

3.6.2 Alarms emitted during the calculation of steels

Calculation with the `ELECTED OFFICIAL` in `CALC_FERRAILLAGE` steels of inflection (`ELS` or `ELECTED OFFICIAL`) can emit one or more alarms in the following cases:

- SI at least a facet is too much compressed out of pivot B
- SI 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
- SI at least a facet is out of pivot C too compressed

The calculation of transverse steels can emit one or more alarms if the concrete is sheared too much.

In all its case the density of reinforcement is fixed at `-1` for the element.

In `COMBINAISON_FERRAILLAGE`, as soon as one of these alarms is emitted for one of the combination of loading, the density of reinforcement of (of) the combination (S) dimensioning (S) is fixed at `-1` and the dimensioning combination is also fixed at `-1`.

3.6.3 Errors emitted during the calculation of steels of inflection

A fatal error is emitted during the calculation of steels of inflection to the `ELS` (`CALC_FERRAILLAGE`) if the compressive stress of the concrete exceeds its maximum value (definite by `SIGM_BETON` for coding `EC2`). This error is raised and transmitted to the user by the means of `COMBINAISON_FERRAILLAGE`.

4 Examples of use

For examples of use one can refer to the CAS-tests *SSLS145* and *SSLS146*.