Operator COMBINATION_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

```plaintext
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_CARACTERISTIQUE',
            / 'ELU_FONDAMENTAL',
            / 'ELU_ACCIDENTEL',
        ♦ / NOM_CAS = l_nomcas [l_K]
            / NUME_ORDRE = l_numeordre, [l_I]
    }

    # if CODING = 'EC2'
    ♦ APFE = _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 = gc, [R]
        ♦ GAMMA_C_BOTTOM = gc, [R]
        ♦ GAMMA_C_ACCI = gc, [R]
        ♦ ALPHA_E = alphae, [R]
        ♦ CLASSE_ACIER = /'with'
            /'B', [DEFECT]
            /'C' [DEFECT]
        ♦ ALPHA_CC = /1.0 [DEFECT]
            /alphacc [R]
        ♦ E_S = be [R]
    }
```

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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 marketable 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 AFFE, § 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 AFFE

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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 Code_Aster (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 (defined 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.