Operator CALC_COUPURE

Summary:
One presents here Lhas order which makes it possible to carry out cuts on elements of plate, starting from the points of end given. The efforts on this line of cut are provided, in the reference mark local of the cut as well as the resulting resultants/moments.

For modal results, the order provides also the modal combinations (Signed CQC and Newmark) according to the spectral method.

Contents

1 Goal

The goal of the comman D E is to realize a rectilinear cut on an element of structure 2D of the type plates (DKT or DST). The furnished information with the user are, according to the selected option:

- the efforts généralis és on the line of cut according to the curvilinear X-coordinate
- resultants or moments resulting from the efforts generalized S on line of cut.

In all the cases, the results provided (efforts or resultants) are calculated in the local reference mark defined by the cut itself. The types of efforts considered are of type `EFGE_NOEU` (efforts generalized with the nodes).

If as starter a result of the type is provided `mode_meca`, the order can providedR at exit also modal combinations of the efforts according to the spectral method.

The exit of the order is a table.

For more information on the spectral method to also refer to the documents [U4.84.01] and [R4.05.03]).

2 Syntax

```
[Table] = CALC_COUPURE (
      ♦  RESULT              = resu              [evol_elas, evol_noli,
                                                 mult_elas, mode_meca]
      ◊  UNITE_MAILLAGE      =  /25,             [DEFECT]
                                / links             [I]
      ♦  OPTION              =  /'EXTRACTION',
                                /'RESULTING',
      ◊  / TOUT_ORDRE = 'YES',                   [DEFECT]
         / NUME_ORDRE = lordre,                  [l_I]
         / LIST_ORDRE = lordre                   [listis]
         / NUME_MODE = l_mode                    [l_I]
         / LIST_MODE = l_mode                    [listis]
         / INST = linst,                         [l_R]
         / LIST_INST = lreel,                    [listr8]
         / FREQ = Lfreq,                         [l_R]
         / LIST_FREQ = Lreality                     [listr8]
         / NOM_CAS = nomcas                      [K24]
          If LIST_FREQ {
            ◊ PRECISION  =  / 1.D-3              [DEFECT]
                            / prec               [R]
            ◊ CRITERION     =  / 'RELATIVE'         [DEFECT]
                            / 'ABSOLUTE'
          }
      ♦  LIGN_COUPE = _F (
         ♦ ENTITLE = txt,                        [KN]
         ♦ NB_POINTS = nbpt,                     [I]
         ♦ COOR_ORIG = (x1, y1, [z1]),           [l_R]
         ♦ COOR_EXTR = (x2, y2, [z2]),           [l_R]
         ♦ GROUP_MA = gma,                       [group_ma]
         ◊ DISTANCE_MAX = distmax,               [R]
         ◊ DISTANCE_ALARME = distala,            [R]
                    ),
      ◊ COMB_MODE = _F (
         ♦ NOM_C ACE = txt,                         [KN]
         ♦ SPEC_OSCI= (spe1, spe2, spe3)            [l_fonction]
         ◊ SCALE = ( ech 1, ech 2, ech 3)        [l_R]
         ♦ MODE_SIGNE = ( num 1, num 2, num 3)      [l_I]
         ♦ TYPE =  'CQC_SIGNE'                   [DEFECT]
         ♦   / AMOR_REDUIT = amor                [l_R]
            / LIST_AMOR = lamor                  [listr8]
                           ),
)
```

3 PrincipleS of operation order

The order takes as starter two points A and B defining the rectilinear cut desired on the plate.

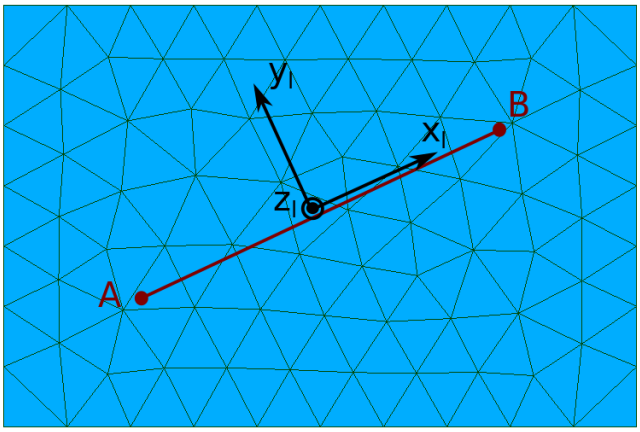

Figure 3-a: Plate with cut AB and local reference mark.

The following operations are carried out:

1) Calculation of the local reference mark of the cut (Figure 3-a) :
   - local direction x_l corresponds to the direction $\overrightarrow{AB}$
   - local direction z_l the normal corresponds to the plate (outgoing of paper in Figure 3-a)
   - local direction y_l is to form an orthogonal reference mark
   - the origin of the reference mark is in the plan of the plate in the medium between the points A and B
2) The field is calculated EFGE_NOEU (if it already do not exist in concept result as starter of the order) in the local reference mark x_l, y_l, z_l .
3) One project the field on the line of cut AB and one recovers the field. If asked by the user, one calculates also resulting efforts and moments on the line of cut.
4) The preceding operations are carried out for each result or static or modal case as starter. If the result is of modal type, the following operations are considered:
   a) Calculation of the modal contribution of the component or the resultant
   b) If the modal combination is requiredE :
      i. Combination of the modes to have the maximum answer most probable by direction (Signed CQC)
      ii. Directional combination of the answersS to have the total maximum answer most probable (Newmark).

4 Components and Résultantes at exit

The components of the generalized efforts of hull are provided in the local reference mark of the cut x_l, y_l, z_l like defined in the Figure 6.5-a :

- NXX , NYY : tractive efforts
- NXY : membrane shearing force
- QX , QY : effortS of shearing out-plan
- MXX , MYY : moments out-plan
- MXY : torsion

Following resultants soundT thatlculées if asked. One chooses by preoccupation with a simplicity the names which one would have if the cut were the cross-section of a cut:

- Normal effort $N = \int_A^B N_{YY}\, dx$
- Membrane shearing OU shearing in the plan $V_{PL} = \int_A^B N_{XY}\, dx$
- Shearing out-plan $V_{HP} = \int_A^B Q_Y\, dx$
- Moment in the plan $M_{PL} = \int_A^B N_{YY} \cdot x\, dx$
- Moment outplan $M_{HP} = \int_A^B M_{YY}\, dx$

R emarque *: the efforts are calculated to leave D U nodal field of the generalized efforts* $EFGE_{NOEU}$ *. This assumption de facto excludes the use of the order to the neighbor has Ge of zone of discontinuity of the efforts, as for a change of material or thickness.*

5 Treatment of the modal results

In this case, the order takes as starter dynamic modes structure (concept mode_meca). The operations carried out are the following ones:

1) Extraction of the efforts or calculation of resultants mode by mode (like).
2) Calcul Dbe answers mode by mode to be left modes and spectra
3) If asked, combination of the modal answers by signed method CQC: that provides the probable maximum answer for each direction of earthquake X , Y , Z (in the total system).
4) If asked, combination Dbe answers direction by direction (Newmark)

The operation 1) is realized as described in the section 4, and that mode by mode.

operations 2-4 are detailedS in the continuation.

Spectra in mono-support are considered: the supports see all same imposed displacement.

5.1 Calculation of the answer of oscillator

5.1.1 Recalls of transitory calculation on modal basis

Lhas studied structure is represented by its spectrum of low frequency real clean modes ϕ in embedded base, solution of $\left(\boldsymbol{K}-\boldsymbol{M}\,\omega^2\right)\phi=0$.

In the dynamic equation of the system one can introduce a new transformation $\boldsymbol{x}=\phi\,\boldsymbol{q}$, the system S' written then, by using the matrix of modal factors of participation $\boldsymbol{P}$:

$$\ddot{\boldsymbol{q}}+\frac{\phi^T\boldsymbol{C}\phi}{\phi^T\boldsymbol{M}\phi}\dot{\boldsymbol{q}}+\omega^2\boldsymbol{q}=-\frac{\phi^T\boldsymbol{M}\boldsymbol{O}}{\phi^T\boldsymbol{M}\phi}\ddot{\boldsymbol{s}}=-\boldsymbol{P}\ddot{\boldsymbol{s}} \tag{1}$$

where $\mathbf{O}$ are the modes of body rigid.

It is also supposed that pour of the industrial studies concerned with the seismic analysis by spectral method, one is limited to the case of damping proportional, known as of Rayleigh, for which one can diagonaliser the term $\frac{\phi^T\boldsymbol{C}\phi}{\phi^T\boldsymbol{M}\phi}=2\,\xi\,\omega$. Damping is then represented by a modal damping ξ_i possibly different for each clean mode.

With these assumptions, the system of equations (2) is composed of independent equations, each one relative to a mode clean of pulsation ω_i . Each equation describes the behavior ofa simple oscillator parameters $\left(\omega_i,\xi_i\right)$ whose behavior is represented in mono-support by:

$$\ddot{q}_i+2\,\xi_i\,\omega_i\,\dot{q}_i+\omega^2 q_i=-p_i\ddot{s} \tag{2}$$

where $\ddot{s}$ is acceleration of training and p_i the modal factor of participation of the mode i :

$$p_i=\frac{\phi_i^T\boldsymbol{M}\boldsymbol{O}}{\phi_i^T\boldsymbol{M}\phi_i}=\frac{\phi_i^T\boldsymbol{M}\boldsymbol{O}}{\mu_i} \tag{3}$$

where μ_i is the generalized modal mass, which depends on the standardisation of the clean mode.

Supposons that it earthquake only acts in Dbe three directionS total reference mark X,Y,Z : if for example one takes it in the direction X , the vector O will have 1 for the degrees of freedom DX and 0 for the others. Always for example in the direction X one will have then:

$$p_{iX}=\frac{\phi_i^T \boldsymbol{M O}}{\phi_i^T \boldsymbol{M}\,\phi_i}=\frac{\phi_i^T \boldsymbol{M O}_X}{\mu_i} \quad (4)$$

p_{iX} being called modal factor of participation in direction X. For more details on the transitory analysis on modal basis to see documentation R4.05.01.

5.1.2 RecallS spectral method

The maximum answer in relative displacement oscillator of parameters (ω_i,ξ_i) for a direction X is given while reading on a spectrum of oscillator of absolute pseudo-acceleration $SRO(\ddot{x}_X(\xi_i,\omega_i))$ the value a_{iX} who corresponds to the cuts (ω_i,ξ_i) and while dividing by ω_i^2, from where:

$$q_{iXmax}=p_{iX}\frac{SRO(\ddot{x}_X(\xi_i,\omega_i))}{\omega_i^2}=p_{iX}\frac{a_{iX}}{\omega_i^2} \quad (5)$$

ON recalls that one posed $\boldsymbol{x}=\phi\,\boldsymbol{q}$ thus $\boldsymbol{x}_i=q_i\phi_i$ if one consider only one mode. The contribution $\boldsymbol{x}_{iXmax}$ of this oscillator to the relative displacement of the structure for an earthquake in direction X depends on the factor on participation and Ldeformed modal ϕ_i in physical space:

$$\boldsymbol{x}_{iXmax}=\phi_i q_{iXmax}=\phi_i p_{iX}\frac{a_{iX}}{\omega_i^2} \quad (6)$$

Let us suppose to have r_i, a quantity (field or scalar variable) derivedE by a linear application of the modes ϕ_i, by example a component ofefforts on a node. The contribution r_{iXmax} Où R_{iX} of this oscillator to the answer of the structure for an earthquake is written also:

$$R_{iX}=r_{iXmax}=r_i q_{iXmax}=r_i p_{iX}\frac{a_{iX}}{\omega_i^2} \quad (7)$$

In the case of the order `CALC_COUPURE`, components r_i are:

- components the effort of hull NXX, NYY, NXY, etc on a point of the line of cut AB
- resultants/moments resulting on the line from cut AB, detailed in the section 4

For more details to see documentation R4.05.03.

5.1.3 Combination of the modes for a direction

First modal combination réaliséE product the probable maximum answer in the directions X,Y,Z for which one will have provided the spectra as starter of the order.

The method used is Combination Quadratic Complète signed (or CQC signed), in mono-support. Efforts R_{iX} (scalar component on a node or a resultant) thus combine in the following way to give the answer R_{mX} :

$$R_{mX}=\frac{R_{kX}}{|R_{kX}|}\sqrt{\sum_j\sum_j \rho_{ij}R_{iX}R_{jX}} \quad (8)$$

The sums are carried out onS N modes considered. One defines the coefficient of correlation between modes ρ_{ij} :

$$\rho_{ij}=\frac{8\sqrt{\xi_i\xi_j\omega_i\omega_j}\left(\xi_i\omega_i+\xi_j\omega_j\right)\omega_i\omega_j}{\left(\omega_i^2-\omega_j^2\right)^2+4\,\xi_i\xi_j\omega_i\omega_j\left(\omega_i^2+\omega_j^2\right)+4\left(\xi_i^2+\xi_j^2\right)\omega_i^2\omega_j^2} \tag{9}$$

or, by introducing the report of pulsation or frequencies between two modes $\eta=\omega_j/\omega_i$:

$$\rho_{ij}=\frac{8\,\eta\sqrt{\xi_i\xi_j\eta}\left(\xi_i+\xi_j\eta\right)}{\left(1-\eta^2\right)^2+4\,\eta\xi_i\xi_j\left(1+\eta^2\right)+4\,\eta^2\left(\xi_i^2+\xi_j^2\right)} \tag{10}$$

For more details voir R4.05.03 documentation.

5.1.4 Combination of the directions

For each direction X,Y,Z , one chooses a principal direction and one calculate them eight values following. For example, for X :

$$R_l=\pm R_{mX}\pm 0{,}4\,R_{mY}\pm 0{,}4\,R_{mZ} \tag{11}$$

One changes then the role of the directions what leads, by circular shift, to 24 values and with:

$$R_m=\max\left(R_l\right) \tag{12}$$

6 Operands

6.1 Operand RESULT

♦ RESULTAT = resu

Name of a concept result of the type [evol_elas, evol_noli, mult_elas, mode_meca].

6.2 Operand OPERATION

Nature of the operation has to carry out:

- S I OPERATION= 'EXTRACTION' values of the field of efforts generalized to the node S EFGE_NOEU are simply restored at exit, in the local reference mark of the cut.
- If OPERATION= 'RESULTANTE' one calculates resultant S and L be moment S on the line of cut.

The local reference mark is calculated automatically:

- axis X : direction of the line of cut
- axis Z : normal direction with the element hull
- axis Y : chosen for creates R an orthonormal base (thus in the plan of the element hull, normal with the line of cut)
-

6.3 Operands TOUT_ORDRE/NUME_ORDRE/NUME_MODE/LIST_ORDRE/INST/LIST_INST/FREQ/LIST_FREQ/PRECISION/CRITERION/NOM_CAS

See documentation [U4.71.00]

6.4 Operand UNITE_MAILLAGE

Specify the logical number of unit in which is created the linear grid of each line of cut. See documentation [U4.81.13].

6.5 Keyword LIGN_COUPE

Keyword répétable allowing to define one or more lines of cut.

A line of cut is made up ofa straight line definedE by its two points ofends and a number of regular intervals Lhas cutting out.

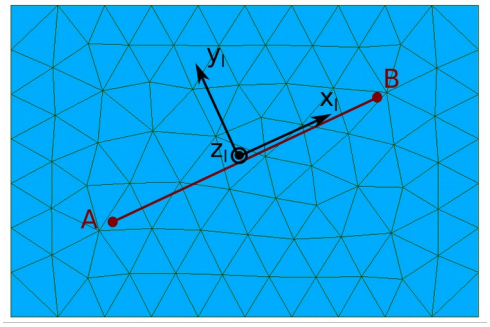

Figure 6.5-a: Line of cut AB on a plate and locates local.

6.5.1 OperandS ENTITLE/NB_POINTS/COOR_ORIG/COOR_EXTR/GROUP_MA/DISTANCE_MAX/DISTANCE_ALARME

See documentation [U4.81.13]

6.1 Keyword COMB_MODE

One provides under this keyword the entries necessary for spectral calculation and the combination of the modes.

6.1.1 Operand NOM_CACE

Label to assign to the combination in the table at exit.

6.1.2 Operand TYPE

Allows to define the type of combination, currently signed method CQC is available.

6.1.3 OperandS SPEC_OSCI/SCALE/ AMOR_REDUIT/LIST_AMOR

See documentation [U4.81. 01]

6.1.4 Operand MODE_SIGNE

Sequence number of a mode (typically principal mode of the structure in the direction) for each direction, used to allot the sign to the efforts (signed method CQC).

6.2 Structure of the table at exit

The execution of the order produces a table which contains the columns described below:

Column	Description
'ENTITLES'	Identify the values of a line of cut, to see operand 'ENTITLES' keyword LIGN_COUPE
'COMB'	Identify the values of a modal combination, to see operand 'NOM_CA' keyword COMB_MODE
'STANDARD'	- 'EXTRACTION' : values of the components of the field EFGE_NOEU on the line of cut in the local reference mark - 'RESULTANT' : resultantS and momentS resulting on the line of cut in the local reference mark - 'RIX', 'RIY', 'RICE' : modal contribution R_{iX} in a given direction X for each resultant, moment or component of effort in the point considered ($a_{iX}=SRO\left(\ddot{x}\left(\omega_i,\xi_i\right)\right)$, p_{iX} modal factor of participation in the direction X). $R_{iX}=r_i\,p_{iX}\,\frac{a_{iX}}{\omega_i^2}$ - 'CQCX', 'CQCY', 'CQCZ' : Ccomplete quadratic ombinaison signed modes in monoappui in a given direction (cf [U4.84.01]) - 'NEWMARK-X-0.4Y-0.4Z',...: combination of the directions according to the criterion of Newmark (cf [U4.84.01]) - 'NEWMARK_MAXABS' : maximum in absolute value enters the combinations
'NOM_CHAM'	'EFGE_NOEU', the field used
'NUME_ORDRE'	Sequence number which identify treated values
'NXX',…, 'QX', 'QY'	Components of the field 'EFGE_NOEU' extracted (see the column 'STANDARD=EXTRACTION', cf also [U2.02.01]) in the calculated local reference mark
'NR'	Normal effort: integral of the component NYY in the local reference mark on the line of cut
'VPL'	Membrane shearing or shearing in the plan: integral of the component NXY in the local reference mark on the line of cut
'MHP'	Moment out-plan: integral of the component MYY in the local reference mark on the line of cut
'VHP'	Shearing out-plan: integral of the component QY in the local reference mark on the line of cut
'MPL'	Moment in the plan: moment of Lhas component NYY (in the local reference mark) on the line of cut, compared to the point of medium of the line of cut.