Operator COMB_SISM_MODAL

1 Drank

Compute a dynamic response with single or multiple imposed motions.

In the case of the multiple excitation, the bearings are animated different motions for a given direction. These motions can be either correlated between them, or perfectly uncorrelated. These requests are represented by response sprectrums of oscillator representing a seisme or a shock. These oscillator spectrums can be given from an accelerogram of seismic signal (real signal or synthetic signal) by the command CALC_FONCTION with the key word factor SPEC_OSCI [U4.32.04].

Operator COMB_SISM_MODAL allows to determine, in any point of structure, the maximum components of relative displacement, relative pseudovelocity, of absolute pseudo-acceleration, the maximum forces generalized by element and the maximum reactions to the bearings.

These maxima of response are calculated from the maximum response of a simple oscillator, associated with each real eigen mode taken into account. Several rules of recombination of the contributions of each eigen mode and the contributions in each direction are available.

This spectral computation is not applicable to the case of a structure with added mass of the fluid type.

Product a concept of the type mode_ meca.

2 Syntax

```
R [mode_stat]  = COMB_SISM_MODAL

       (   ♦MODE_MECA     = mode                              [mode_meca]
           ◊/TOUT_ORDRE      = "OUI'                      [DEFAULT]
              /NUME_ORDRE    = l_ordre                   [l_I]
              /LIST_ORDRE    = lordre                    [listis]
              /NUME_MODE      = l_mode                      [l_I]
              //FREQ     =      l_freq                 [l_R]
                 /LIST_FRE  Q = lfreqr8               [listr8]
                     ◊  I accuracy =/1.D-3                [DEFAULT]
                                   /prec                  [R]
                        I CRITERE =        "RELATIF"          [DEFAULT]
                                   /  "ABSOLU"

           ◊MODE_CORR     = acce
[mode_stat_acce]

           ♦   /AMOR_REDUIT  = amor                        [l_R]
              /LIST_AMOR      = lamor                     [listr8]
              /AMOR_GENE       = amogene                  [matr_asse_gene_R]

           ◊   MASS_INER      = mass_iner
[tabl_mass_iner]

            ♦   /MONO_APPUI   = "OUI'
              /   MULTI_APPUI=' CORRELE'
              /   MULTI_APPUI='DECORRELE'
           ♦EXCIT  =_F (♦/NOEUD=             lno                  [l_noeud]
                          /GROUP_NO     = lgrno            [l_gr_noeud]

                       ♦/♦AXE              = (c1, c2, c3)   [l_R]
                             ♦SPEC_OSCI     = spec                  [three-
dimensions function]
                             ◊ECHELLE     = echel            [R]

                          /♦TRI_AXE       = (p1, p2, p3)    [l_R]
                             ♦SPEC_OSCI     = spec                  [three-
dimensions function]
                             ◊ECHELLE     = echel            [R]

                          /♦TRI_SPEC        = "YES"         [kN]
                             ♦SPEC_OSCI=   (spe1, spe2, spe3)  [l_fonction]
                             ◊ECHELLE=  (ech1, ech2, ech3)  [l_R]

                       ◊NATURE    =      "ACCE"                [DEFAULT]
                                  /  "QUICKLY"
                                  /  "DEPL"
                      )

           ◊CORR_FREQ     =      "OUI'                        [DEFAULT]
                          /  "NON"

           ♦COMB_MODE     =_F ( ♦/TYPE     =         "GUPTA"
                                             /  "SRSS"
                                             /  "CQC"
                                             /  "DPC"
                                             /  "AB"
                                             /  "DSC"
                                ◊   DUREE = S                   [R]
```

```
                                             ◊   FREQ_1 = Hz                [R]
                                             ◊   FREQ_2 = Hz                [R]
                                        )
                  ◊COMB_DIRECTION   =_F (     ♦/TYPE     =      "QUAD"
                                                               /   "NEWMARK"
                                             )
              ◊COMB_MULT_APPUI  =_F (
                                              ♦/  TOUT = "OUI'
                                                   /NOEUD = lno     [l_noeud]
                                                   /GROUP_NO =lgrno    [l_gr_noeud]
                                              ♦/  TYPE_COMBI =   "QUAD"
                                                                  /"LINE"

                                                    )
              ◊GROUP_APPUI =_F (
                                              ♦    /NOEUD = lno     [l_noeud]
                                                   /GROUP_NO =lgrno    [l_gr_noeud]

                                                    )
              ◊DEPL_MULT_APPUI  =_F (
                                              ♦NOM_CAS   = nomcas
                                              ♦NUMÉRIQUE_CAS    = numcas
                                              ◊   NOEUD_REFE = noeu    [node]
                                              ♦MODE_STAT    = stat
       [mode_stat_depl]
                                              ♦   /NOEUD  = lno     [l_noeud]
                                                  /GROUP_NO  = lgrno   [l_gr_noeud]
                                              ♦    I DX =   dx          [R]
                                                   I DY =   Dy          [R]
                                                   I DZ =   dz          [R]
                                             )
              ◊COMB_DEPL_APPUI  =_F (
                                              ♦/TOUT     = "/LIST_CAS
                                                 OUI'    = list    [l_nume]
                                              ♦/TYPE_COMBI      =  "QUAD"
                                                                  /"LINE"
                                                                   /"AB"
                                                    )
                   ♦  OPTION =      I  "DEPL"
                                    I "QUICKLY"
                                    I "ACCE_ABSOLU"
                                    I "SIGM_ELNO"
                                    I "SIEF_ELGA"
                                    | "SIPO_ELNO"
                                    | "EFGE_ELNO"
                                    I "REAC_NODA"
                                    I "FORC_NODA"
                  ◊TITER  = tit                                  [l_Kn]
                  ◊INFO   = /1                                   [DEFAULT]
                                 /2
                  ◊IMPRESSION   =_F ( /TOUT=     "OUI'           [DEFAULT]
                                        /NIVEAU      =  I "SPEC_OSCI"
                                                        I "MASS_EFFE"
                                                        I "MAXI_GENE"
                                    )
              )
```

3 Operands

This computation spectral is not applicable to the case of a structure with added mass of the fluid type because it is necessary that the concept modal base is resulting from a computation on physical and not generalized coordinates.

3.1 Definition of the eigen modes of the structure

3.1.1 Operand MODE_MECA

♦MODE_MECA = Name

mode of the concept of the mode_meca `type` produces by one of the operators of modal analysis `MODE_ITER_SIMULT` [U4.52.03] or `MODE_ITER_INV` [U4.52.04].

3.1.2 Operands TOUT_ORDRE / NUME_ORDRE / NUME_MODE/LISTE_ORDRE

/TOUT_ORDRE = "OUI'

Default value which makes it possible to extract all the eigen modes available in the concept `mode`.

/NUME_ORDRE = l_ordre
/NUME_MODE = l_mode

Extraction of the eigen modes defined by a list `l_ordre` of sequence numbers (`NUME_ORDRE`) or a list `l_mode` of numbers of modes (`NUME_MODE`).

/LIST_ORDRE = l_ordre

Idem `NUME_ORDRE` but of listis `type` (produced by `DEFI_LIST_ENTI`).

3.1.3 Operand FREQ / LIST_FREQ / accuracy / CRITERE

/FREQ = l_freq

Makes it possible to extract the eigen modes corresponding to a list from frequencies `l_freq`.

/LIST_FREQ = lfreqr8

Makes it possible to extract the eigen modes corresponding to a list of frequencies `lfreqr8`, definite by the operator `DEFI_LIST_REEL` [U4.34.01] (`lfreqr8` is thus a concept of the listr8 `type).`

◊ | PRECISE DETAILS = prec
| CRITERE =

These operands make it possible to indicate that one searches all the eigen modes of which the frequency is in the interval $inst \pm prec$. By default $prec = 1.0\mathrm{D}-3$.

According to the value of key word `CRITERE` :

"RELATIF": the interval of search is:

$$[inst(1-prec), inst(1+prec)]$$

"ABSOLU": the interval of search is:

$$[inst-prec, inst+prec]$$

3.2 Definition of modal dampings

Three possibilities exist to define modal dampings: a list of reduced dampings provided by the user in the form of list of realities (`l_R`) or of a concept of the listr8 `type` builds DEFI_LIST_REEL `by the operator` [U4.34.01] or a generalized damping matrix (damping matrix projected on the basis of real eigen mode).

3.2.1 Operand **AMOR_REDUIT**

`/AMOR_REDUIT = amor`

This operand makes it possible to provide the list of reduced dampings in the form of a list of realities (`l_R`). If the number of provided coefficients is lower than the numbers of eigen modes taken into account, the last coefficient is allotted to the mode corresponding and the following modes.

3.2.2 Operand **LIST_AMOR**

`/LIST_AMOR = lamor`

This operand makes it possible to provide the list of reduced dampings in the form of a concept of the listr8 `type`. If the number of reduced dampings is lower than the number of eigen modes taken into account, the last coefficient is affected with the following modes.

Example:

```
TOUT_ORDRE = "OUI'
LIST_AMOR = ("0.01", "0.02")
```

first mode $\xi=0.01$ and for all the other modes $\xi=0.02$

3.2.3 Operand **AMOR_GENE**

`/AMOR_GENE = amogene`

One gives the name of the damping matrix by the operator `generalized` amogene produced `PROJ_MATR_BASE` [U4.63.12] or `PROJ_BASE` [U4.63.11].

3.3 Operand **MASS_INER**

to check the criterion of office plurality of the unit effective masses of the eigen modes taken into account in each direction, it is necessary to know the total mass of structure.

This one is calculated by the command `POST_ELEM` [U4.81.22] with key word `MASS_INER`. Operand `MASS_INER` makes it possible to provide the name of the product concept by this command.

3.4 Definition of the type of the excitation (mono or multi-supported)

Three configurations are possible:

- the structure is studied with same motion of training in all the bearings;
- the structure is studied with several different motions of training to the bearings, all correlated between them;
- the structure is studied with several different motions of training to the bearings, whose one can display perfectly uncorrelated groups between them, the excitations inside the same group of bearings being supposed correlated between them.

3.4.1 Operand **MONO_APPUI**

`/MONO_APPUI = "OUI'`

the excitations with the bearings are all equal.

3.4.2 Operand **MULTI_APPUI**

```
/MULTI_APPUI  = ' CORRELE'
```

the excitations with the bearings all are correlated between them (they can be different or equal).

```
/MULTI_APPUI  = ' DECORRELE'
```

the excitations with the bearings can be gathered so that one can display groups (possibly made up of only one bearing) perfectly uncorrelated between them; inside the same group, the bearings are supposed to be correlated between them.

3.5 Description of the excitation: key word EXCIT

the seismic excitation is defined by one or more oscillator spectrums. Those are calculated as a preliminary by the command CALC_FONCTION [U4.32.04] or are read on a file by the command LIRE_FONCTION [U4.32.02]. In both cases, the product concept is of standard function with two variables (three-dimensions function).

One uses for that factor key word

```
the ♦EXCIT
```

and possibly operand CORR_FREQ.

3.5.1 Operands NOEUD / GROUP_NO

One for each occurrence specifies factor key word nodes or nodes groups concerned with the described excitation:

```
/NOEUD     = lno
/GROUP_NO  = lgrno
```

3.5.2 Excitation along an axis

```
/♦AXE            = (c1, c2, c3)
   ♦SPEC_OSCI     = spec
   ◊ECHELLE      = echel
```

In this case, one provides:

- the cosine directors $(c1\,c2\,c3)$ of the axis of excitation in reference GLOBAL of definition of mesh: the coefficients $c1, c2, c3$ are renormés by the command,
- operand SPEC_OSCI expects only one oscillator spectrum where spec is the name of the three-dimensions function to be used,
- operand ECHELLE makes it possible to define a scale factor echel to be applied to all the points of the spectrum spec.

Example:

For an excitation with 45° compared to reference GLOBAL, a spectrum of soil sol_0_1 fixed with $0.1\,g$ and a scale factor allowing to simulate a spectrum fixed with $0.25\,g$:

```
AXE = (1. , 1. , 0.),
SPEC_OSCI=sol_0_1,
ECHELLE=2.5,
```

3.5.3 triaxial Excitation with only one spectrum

```
/♦TRI_AXE       = (p1, p2, p3)
   ♦SPEC_OSCI     = spec
```

◊ECHELLE = echel

In this case, one provides:

- the weight coefficients $(p1\ p2\ p3)$ to be applied to the oscillator spectrum for each direction X, Y and Z,
- operand SPEC_OSCI expects only one oscillator spectrum where spec is the name of the three-dimensions function to be used,
- operand ECHELLE makes it possible to define a scale factor echel to be applied to all the points of the spectrum spec, independently of the weight coefficients of direction.

Example:

For an excitation with a weighting of $1.$ in X and in Y (horizontal plane) and 0.66 in Z (vertical), a spectrum of soil fixed with $0.1\,g$ and a scale factor allowing to simulate a spectrum fixed with $0{,}25\,g$:

```
TRI_AXE= (1. , 1. , 0.66),
SPEC_OSCI=sol_0_1,
ECHELLE=2.5,
```

3.5.4 triaxial Excitation with three different spectrums

```
/♦TRI_SPEC        = "OUI'
   ♦SPEC_OSCI     = (spe1, spe2, spe3)
    ◊  ECHELLE    = (ech1, ech2, ech3)
```

In this case one provides:

- operand TRI_SPEC: "OUI',
- operand SPEC_OSCI expects three oscillator spectrums where (spe1 spe2 spe3) is the list of the three-dimensions functions to be used in the three directions X Y Z.
- operand ECHELLE makes it possible to define three scale factors (ech1 ech2 ech3) to apply independently to all the points of each spectrum.

3.5.5 Operand NATURE

◊NATURE

This operand makes it possible to specify the quantity of the oscillator spectrum. By default, one uses a spectrum of acceleration "ACCE". It is possible to more rarely use of other quantities: velocity "QUICKLY" or displacement "DEPL".

3.5.6 Operand CORR_FREQ

◊CORR_FREQ

To compute: the components of response of velocity or in acceleration from an oscillator spectrum of the quantity displacement (NATURE = "DEPL"), one is led to multiply each value one or twice by ω_r pulsation of the real eigen mode (oscillating undamped). In any rigor the oscillator r is damped and its own pulsation is $\omega_r\sqrt{1-\xi^2}$ and ω_r is only the own pseudo-pulsation. By default, one thus obtains:

$$vite_{max} = \omega_r depl_{lu} = pseudo-vitesse$$
$$acce_{max} = \omega_r^2 depl_{lu} = pseudo-accélération$$

Operand CORR_FREQ: "OUI' makes it possible to correct these values to take into account the damping of the eigen mode:

$$vite_{max} = \omega_r\sqrt{1-\xi^2}\, depl_{lu} = vitesse$$
$$acce_{max} = \omega_r^2\left(1-\xi^2\right) depl_{lu} = accélération$$

If one provides a response sprectrum velocity (NATURE = "QUICKLY") operand CORR_FREQ is necessary to correct $depl_{max}$ and $acce_{max}$ if necessary. In the same way for a response sprectrum in acceleration (NATURE = "ACCE") to correct $depl_{max}$ and $vite_{max}$.

In all the cases, one will take care not to use like data SPEC a spectrum pseudo - quantity.

3.6 Combination rules

to evaluate one raising of the response of structure, one reasons quantity by quantity (displacement, velocity or acceleration, internal forces, stresses) starting from the modal values associated with the eigen modes taken into account. For each quantity, one will treat **independently** each degree of freedom (fields at nodes of displacement, velocity or acceleration), or each component of torsor (internal forces) or stress. It is what we call the response R in the statement of the combination rules.

Several levels of combinations are necessary:

- combination of the eigen modes,
- static correction by pseudo-mode,
- combination according to the directions of seisme.

In the case of an analysis multi-bearing, the combination rules are modified to take account of the various excitations applied to groups of bearings. It is also possible to separately calculate the primary and secondary components of the response.

3.7 Combination rules for an excitation mono-bearing

the total **response** of structure R is obtained by **combination of directional responses** R_X where X represents one of the directions of reference GLOBAL of definition of the mesh (X, Y, Z) or a particular direction (cf operand AXE). The directional response is given by:

$$R_X=\sqrt{R_d^2+(R_t+R_{qs})^2+R_e^2}$$

- R_d dynamic combined response of the modal oscillators established by key word COMB_MODE [§ 3.7.1]
- R_t correction of the static effects of the neglected modes (pseudo-mode) [§ 3.7.2]
- R_{qs} formula response combined of the modal oscillators established by key word COMB_MODE (TYPE = ' GUPTA') [§ 3.7.1.6]
- R_e contribution of the motion of training ($R_e=0$ out of mono-bearing)

the combination rule of directional responses is defined by key word COMB_DIRECTION [§ 3.6.3].

3.7.1 Combination of the eigen modes: key word COMB_MODE

♦COMB_MODE

the response of structure R_d , **in a direction of seisme**, is obtained by one of the possible combinations (defined by operand TYPE) of the contributions of each eigen mode taken into account. Each eigen mode is regarded as an oscillator independent of response R_r definite par. (ω_r, ξ_r) the response is read by interpolation in the oscillator spectrum of the signal of excitation in this direction.

For an excitation mono-bearing, the response R_r of the oscillator r is given by:

$$R_r = \frac{p_r}{\omega_r^2} S_r \Phi_r$$

- Φ_r modal quantity (displacement, generalized force, reaction) associated with the modal eigen mode of r
- P_r index participation factor associated with the mode r in the studied direction
- S_r value of the response sprectrum, for example in pseudo-acceleration, for the oscillator r

Several combination rules of the eigen modes are available. They are chosen by operand `TYPE`.

3.7.1.1 Quadratic combination `TYPE = "SRSS"`

This combination (Public garden Root of Sum of Squares) corresponds to the assumption of strict independence of the oscillators associated with each eigen mode:

$$R_d = \sqrt{\sum_{r=1}^{nmod} R_r^2}$$

Let us note that this combination rule, although very usually used, can be badly adapted when the assumption of independence is not checked for nearby eigen modes or with important damping.

3.7.1.2 Complete quadratic combination `TYPE = "CQC"`

the quadratic combination (established by DER KIUREGHIAN [bib1]) makes a correction to the preceding rule by introducing coefficients of correlation depending on depreciation and the distances between close eigen modes (cf [R4.05.03]):

$$R_d = \sqrt{\sum_{r_1} \sum_{r_2} \rho_{r_1 r_2} R_{r_1} R_{r_2}}$$

with the coefficient of correlation:

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

3.7.1.3 Somme absolute values `TYPE = "AB"`

This combination corresponds to an assumption of complete dependence of the oscillators associated with each eigen mode:

$$R_d = \sum_{r=1}^{nmod} \left|R_r\right|$$

Let us note that this combination rule is to be disadvised, because it too strongly preserving and is led to a systematic oversizing.

3.7.1.4 Combination with rule of the 10% TYPE = "DPC"

the close modes (of which the frequencies different from less than 10%) are initially combined by summation of the absolute values. The values resulting from this first combination are then combined quadratically. This method was proposed by American regulation U.S. Nuclear Regulatory Commission (Regulatory Guides 1.92 - February 1976) to attenuate the conservatism of the preceding method. It remains at fault for structures with a dense frequency spectrum clean.

3.7.1.5 Combination of ROSENBLUETH TYPE = "DSC"

This rule (proposed by E. ROSENBLUETH and J. ELORDY [bib2]) introduced a correlation between modes, different from that of method CQC. The responses of the oscillators are combined by double sum (Double Sum Combination):

$$R_d=\sqrt{\sum_{r_1}\sum_{r_2}\rho_{r_1 r_2} R_{r_1} R_{r_2}}$$

It requires an additional data, period s of the "strong" phase of the seisme defined by operand DUREE.

The coefficient of correlation is then:

$$\rho_{ij}=\left(1+\left(\frac{\omega'_i-\omega'_j}{\xi'_i\omega_i+\xi'_j\omega_j}\right)^2\right)^{-1}$$

$$où \quad \omega'_i=\omega_i\sqrt{1-\xi_i^2} \quad et \quad \xi'_i=\xi_i+\frac{2}{s\,\omega_i}$$

3.7.1.6 Combination according to Gupta TYPE = "GUPTA"

Gupta [NRC1.92], to take into account the correlations between modes due to the quasi-static part of the response, introduced the rigid factor of response, which varies from 0 to 1 the correlation between the modal responses of intermediate frequencies between $FREQ_1$ and $FREQ_2$, two frequencies to be determined by the user.

Gupta breaks up each modal response R_r in a dynamic part R_r^p and a quasi-static part R_r^{qs} : $R_r^{qs}=\alpha_r R_r$ and $R_r^p=\sqrt{1-\alpha_r^2}\,R_r$

Thus, for each mode r, one affects the rigid factor of response α_r with the modal response R_r :

$\alpha_r=0$ for $f\le f_1$ $\quad$ $\alpha_r=1$ for $f\ge f_2$

α_r estimated for the frequency f_r according to the following formula:

$$\alpha_r=\frac{\ln f_r/f_1}{\ln f_2/f_1}$$

the dynamic combined response of the modal oscillators is carried out according to combination "CQC":

$$R_d=\sqrt{\sum_{r_1}\sum_{r_2}\rho_{r_1 r_2} R_{r_1}^p R_{r_2}^p}$$

the quasi-static combined response of the modal oscillators is carried out according to an algebraic combination:

$$R_{qs}=\sum_{r=1}^{nmod} R_r^{qs}$$

This combination according to GUPTA is available only in the case mono-bearing.

3.7.2 Static correction by pseudo-mode: operand MODE_CORR

modal base used is in general incomplete. The evaluating of raising response to a seismic excitation requires, so a correction by a term representing the static contribution of the neglected eigen modes, in each direction of seisme.

For each direction of the seisme, one carries out this correction, while adding to modal base, a pseudo - mode ψ obtained from a static mode φ, field of displacements of the nodes of structure subjected to a constant acceleration **in the direction considered** defined by:

$$\boldsymbol{K}\,\varphi=\boldsymbol{M}\,\delta$$

- $\boldsymbol{K}$ stiffness matrix of the structure
- $\boldsymbol{M}$ mass matrix of the unit
- δ structure field in the direction of the seisme

the pseudo-mode ψ is obtained by withdrawing the static contributions of the modes taken into account:

$\Psi=\varphi-\sum_{r=1}^{nmod}\frac{p_r}{\omega_r^2}\Phi_r$ with:

- Φ_r eigen mode of index r
- P_r participation factor in the direction δ

In this direction δ, for each quantity, the modal contribution neglected is given by:

$$R_t=R_s-\sum_{r=1}^{nmod}R_r$$

R_s associated with the static mode ◊MODE_CORR is

`the quantity  = acce`

This key word makes it possible to provide it (S) field (S) of displacements φ of the nodes of structure subjected to a constant acceleration in one (or several) direction (S), field (S) calculated (S) by the operator `MODE_STATIQUE` with key word `PSEUDO_MODE` [U4.52.14]. For any direction of seisme where the response is calculated, one calculates a pseudo-mode if `acce` is provided.

3.7.3 Combination according to the directions: key word COMB_DIRECTION

◊`COMB_DIRECTION`

Two combination rules of directional responses are available. They are chosen by operand `TYPE`.

3.7.3.1 Quadratic combination: TYPE = "QUAD"

This combination corresponds to the assumption of strict independence of the responses in each direction:

$$R=\sqrt{R_X^2+R_Y^2+R_Z^2}$$

3.7.3.2 Combination of NEWMARK: TYPE = "NEWMARK"

For each direction $i(X, Y, Z)$, one calculates the 8 values:

$$R_i=\pm R_X\pm 0{,}4\,R_Y\pm 0{,}4\,R_Z$$

What leads, by circular shift, with 24 values and

$$R=max(Ri)$$

3.8 Case of an excitation multi-bearing

Two processing is envisaged [feeding-bottle 3]:

- Computation of the total response
- Computation of the components primary and secondary of the response

In the case of the multiple excitation, these bearings are animated different motions for a given direction. 2 distinct cases then are distinguished:

- either these motions all are correlated between them (case correlated excitations),
- or one can display at least 2 groups of perfectly uncorrelated bearings, the bearings constitutive of the same group being correlated between them (case uncorrelated excitations).

3.8.1 Computation of the total response

Compared to the mono-bearing, an additional combination is necessary. The flow diagram for treatment differs according to whether the excitations are correlated or uncorrelated.

3.8.1.1 Excitations correlated

•For each mode of index j, one calculates the directional responses modal ones R_{Xj} by combination of directional responses modal of bearing R_{Xij}. The combination rule is defined by the key word `COMB_MULT_APPUI` [§ 3.8.3].

•One calculates the directional responses R_X definite ones by:

$$R_X=\sqrt{R_{Xd}^2+R_{Xt}^2+R_{Xe}^2}$$

- R_{Xd} is the combined response of directional responses modal drawn up by the key word `the COMB_MODE` [§ 3.7.1];
- R_{Xt} represent the static correction of the neglected modes. This term is obtained by algebraic office plurality of the pseudo-modes of bearing;
- R_{Xe} represent the motion of training. This term is obtained by algebraic combination of motions of training of bearing.

•The total response R of structure is obtained by combination of directional responses R_X. The combination rule is defined by key word `COMB_DIRECTION` [§ 3.7.3].

3.8.1.2 Uncorrelated excitations

- One defines the possible groups of bearings using key word `GROUP_APPUI.` The responses of the modal oscillators of the same group of bearings are combined linearly (not choice left to the user for this office plurality intra-group).
- For each bearing or groups bearings subscripted by i, subjected to a different excitation, one calculates directional responses bearings R_{Xi} defined by:

$$R_{Xi}=\sqrt{R_{Xdi}^2+R_{Xti}^2+R_{Xei}^2}$$

- R_{Xdi} is the combined response of the modal oscillators drawn up by key word `COMB_MODE` [§ 3.7.1].
- R_{Xti} represent the correction of the static effects of the neglected modes. The term differs from the case mono-bearing. The computation similar but is utilized the field of

displacements of structure subjected to a unit acceleration of bearing I in the direction X [bib3];
- R_{Xei} is the contribution of the motion of training of bearing i ($R_{ei}\neq 0$ out of multi-bearing) established by the key word DEPL_MULT_APPUI [§ 3.8.5].

- One calculates directional responses R_X by combination of directional responses of bearings R_{Xi}. The groups of uncorrelated bearings being supposed between them, directional responses of bearings are combined quadratically (not choice left to the user).

- The total response R of structure is obtained by combination of directional responses R_X. The combination rule is defined by key word COMB_DIRECTION [§ 3.7.3].

3.8.2 Partition of the components primary and secondary of the response

For the seismic analysis of the multimedia pipework, the partition of the components inertial and quasi-static of the response can prove to be necessary for a postprocessing RCC-M [bib3].

3.8.2.1 Inertial primary component

It acts of the inertial response induced by the accelerations imposed on anchorages (SRO). One renews the processing adopted for the total response by removing the contribution of the motion of training.
The order of the combinations to be carried out differs according to whether the energizations of the bearings all are correlated between them or that they set up uncorrelated groups between them.

- <u>Bearings correlated</u>

  - For each modal oscillator j, one calculates the directional responses modal ones (office plurality on the bearings) $R_{IXj}=\sqrt{R_{dj}^2+R_{tj}^2}$ with:
    - R_{dj} combined modal response of the modal oscillators (office plurality on the bearings). The combination rule is defined by the key word COMB_MULT_APPUI [§ 3.8.3].
    - R_{tj} contribution of the static correction of the neglected modes (pseudo-mode of bearing)
  - One calculates directional responses R_{IX} by combination of directional responses modal R_{IXj}, using key word COMB_MODE [§ 3.7.1].

- <u>Uncorrelated groups of bearings</u>

  - One defines the possible groups of bearings using key word GROUP_APPUI. The responses of the modal oscillators of the same group of bearings are combined linearly (not choice left to the user for this office plurality intra-group).
  - For each bearing or groups bearings subscripted by i, subjected to a different excitation, one calculates directional responses primary education bearings R_{IXi} defined by:

$$R_{IXi}=\sqrt{R_{di}^2+R_{ti}^2}$$

    - R_{di} combined response of modal oscillators established by the key word COMB_MODE [§ 3.7.1]
    - R_{ti} represents the correction of the static effects of the neglected modes. The term differs from the case mono-bearing. The computation similar but is utilized the field of displacements of structure subjected to a unit acceleration of bearing I in the direction X [bib3].
  - One calculates directional responses R_{IX} by combination of directional responses of bearings R_{IXi}. The groups of uncorrelated bearings being supposed between them, directional responses of bearings are combined quadratically (not choice left to the user).

The primary total response R_I of structure is obtained by combination of directional responses R_{IX}. The combination rule is defined by key word COMB_DIRECTION [§ 3.7.3].

3.8.2.2 Differential secondary component

It acts of the static response induced by seismic differential displacements of the anchorages (motion of training):

- Computation of the contribution R_{ei} of the motion of training of bearing i established by the key word DEPL_MULT_APPUI [§ 3.8.5]
- Combinations of the various contributions of bearing defined R_{ei} by the key word COMB_DEPL_APPUI [§ 3.8.6].

It is thus possible to reconstitute:

- lawful loading cases corresponding to:
  - an overall motion of part of the bearings in a given direction
  - a displacement mentioned in a local coordinate system different from the total reference of inertial seismic request;
- directional responses by combining the adequate contributions of bearings;
- the total secondary response.

Examples are proposed in [§ 3.8.6.6].

3.8.3 Key word COMB_MULT_APPUI (case MULTI_APPUI=CORRELE)

◊COMB_MULT_APPUI

the occurrences of this key key make it possible to define:
- combinations of directional responses modal of bearing to form the directional responses modal ones (case of the correlated excitations);
- combinations of directional responses of bearing to form directional responses structure (case of the uncorrelated excitations).
If the occurrences of key key COMB_MULT_APPUI are present, it is the primary component of the response which is treated.

The combination of the contributions of each motion of bearing can be combined various ways, defined by operand TYPE_COMBI:

- quadratic combination
- linear combination

3.8.3.1 Operands TOUT/NOEUD/GROUP_NO

♦/TOUT = "OUI'

Makes it possible to choose that all the bearings are combined with the rule defined by TYPE

/NOEUD = lno [l_noeud]
/GROUP_NO = lgrno [l_group_no]

Makes it possible to define the list of the bearings (or groups of bearings) which are combined with the rule defined by operand TYPE_COMBI in the same occurrence of key word COMB_MULT_APPUI.

3.8.3.2 Quadratic combination TYPE = "QUAD"

$$R_X = \sqrt{\sum R_{Xj}^2}$$

It is advised to use this combination only when motions of bearing are uncorrelated.

3.8.3.3 Linear combination TYPE = "LINE"

$$R_X = \sum R_{Xk}$$

3.8.3.4 Combination rules different on the various bearings

the combination rule can be the same one for all the bearings [§ 3.7.3.1] or differentiated according to the bearings or groups of bearings defined by an occurrence of the key word factor COMB_MULT_APPUI. In this case the total response - or the primary component of the response if COMB_DEPL_APPUI is present - is obtained by:

$$R = \sqrt{\sum R_{Xj}^2 + \left(\sum R_{Xk}\right)^2}$$

where j indicates the bearings combined quadratically and k linearly combined bearings.

3.8.4 Key word GROUP_APPUI (case MULTI_APPUI=DECORRELE)

◊ GROUP_APPUI

If this key word is absent, all the bearings is regarded as uncorrelated between them.
This key word is used only if one can display one or more groups of uncorrelated bearings between them, the bearings constitutive of a group being correlated between them. A group can be made up of only one bearing.
The occurrences of this key word make it possible to define the groups of bearings. The bearings not belonging to a group are regarded as uncorrelated between them and uncorrelated definite groups.

The combination of the contributions of each motion of bearing inside a group can be realized only in a linear way. The combination of the contributions of each group of bearings can be realized only in a quadratic way (not of choice left to the user).

3.8.4.1 Operands TOUT / NOEUD / GROUP_NO

♦ /NOEUD = lno [l_noeud]
/GROUP_NO = lgrno [l_group_no]

Makes it possible to define the list of the groups of bearings.

3.8.5 Key word DEPL_MULT_APPUI

◊DEPL_MULT_APPUI

the motion of training of structure not being uniform this key word makes it possible to define the contribution to the total response of a list of bearings or groups of bearings. This one is established starting from the static modes of structure:

$$R_{ei} = \Phi_{si} \delta_{i\,max}$$

with:

Φ_{si} static mode for the bearing i

$\delta_{i\,max}$ maximum displacement of the bearing i compared to a bearing of reference (for which $\delta_{i\,max} = 0$)

If this key word is not indicated, then the modal contribution statics of structure is null. In other words, this is equivalent to informing $\delta_{i\,max}=0$.

3.8.5.1 Operand NOM_CAS/NUMÉRIQUE_CAS

♦ NOM_CAS = nomcas
Character string defining the name of the loading case

• NUME_CAS = numecas
Number of the loading case

3.8.5.2 Operand MODE_STAT

◊MODE_STAT = stat

Name of the static modes Φ_{si} , concept of the mode_stat type produces MODE_STATIQUE [U4.52.14] by the operator.

3.8.5.3 Operand NOEUD_REFE

◊NOEUD_REFE = noeu

Node of referenced by ratio to which relative displacements of the bearings are defined.
If this operand is present, the maximum displacement applied to the bearing i is worth $\delta_{i\,max}-\Delta$ where Δ is affected displacement with the node of reference noeu in the direction considered.

3.8.5.4 Operands NOEUD / GROUP_NO

♦ /NOEUD = lno
/GROUP_NO = lgrno

List of the names of nodes (or nodes groups) corresponding to the bearings concerned with the occurrence of the key word factor DEPL_MULT_APPUI.

3.8.5.5 Operands DX / DY / DZ

♦ I DX = dx
I DY = Dy
IDZ = dz

Valeur of maximum relative displacement of the bearings concerned, direction by direction.

3.8.6 Key word COMB_DEPL_APPUI

◊COMB_DEPL_APPUI

the occurrences of this key key define the combinations of the lawful loading cases intervening in the secondary component of the response.

3.8.6.1 Operands TOUT/LISTE_CAS

♦/TOUT = "OUI'
All the loading cases defined under the occurrences of DEPL_MULT_APPUI are combined with a single rule specified by TYPE

/LISTE_CAS = list

Numbers of the loading cases combined with the rule specified by quadratic

3.8.6.2 TYPE Combination TYPE = "QUAD"

$$R_e=\sqrt{\sum R_{ej}^2}$$

3.8.6.3 Combination linear TYPE = "LINE"

$$R_e=\sum R_{ek}$$

3.8.6.4 Combination in absolute value TYPE = "AB"

$$R_e=\sum |R_{el}|$$

3.8.6.5 Combination rules different on the various loading cases

the combination rule can be the same one for all the cases of displacement of anchorage or differentiated according to the groups of cases defined by an occurrence of the key word factor COMB_DEPL_APPUI. In this case the secondary total response is obtained by:

$$R_{II}=\sqrt{\sum R_{ej}^2+\left(\sum R_{ek}\right)^2+\left(\sum |R_{el}|\right)^2}$$

where j indicates the bearings combined quadratically, k bearings combined linearly and l bearings combined in absolute value.

3.8.6.6 Examples of Displacement

•application expressed in a local coordinate system $R_{loc}(x, y, z)$ different from the total reference $R_{glob}(X, Y, Z)$

axes x, y and z R_{loc} are built by 3 successive rotations of angle α, β and γ around the axes X, Y and Z of R_{glob}.

To simplify the example, it is considered that R_{loc} results from R_{glob} a single rotation around the axis X and of angle α and that the local displacement u_x of the support S located with the node NS is given along the axis x of R_{loc}.

This loading case results from the linear combination of 2 static modes and results in the algebraic summation of the 2 following loadings:

•displacement $DX=u_x \cos\alpha \, depl\, X$ following the axis X
•displacement $DY=u_x \sin\alpha \, depl\, Y$ along the axis Y

the static modes of bearing following the directions X and Y are calculated beforehand.
The taking into account of the loading case is written with following syntax:

```
DEPL_MULT_APPUI= (
             _F (
                NOM_CAS=' uxcos',
                NUME_CAS=1,
                MODE_STAT=modstat,
                NOEUD=' NS',
                DX=deplX,
                ),
             _F (
                NOM_CAS=' uxsin',
                NUME_CAS=2,
                MODE_STAT=modstat,
                NOEUD=' NS',
                DY=deplY,
                ),
                   ),
COMB_DEPL_APPUI= (
             _F (
                LIST_CAS= ("1", "2"),
                TYPE_COMBI =  ' LINE'
                ),
```

•overall Motion in a direction

Let us consider one line anchored on 3 supports $S1$, $S2$ and $S3$. An overall motion U is applied to the supports $S1$, $S2$ in the direction X. The support $S3$ related to the crossing of a building is supposed to be fixed.
The static modes of bearing in the direction X on the level of the supports $S1$ and $S2$ are calculated beforehand.
The taking into account of the loading case is written with following syntax:

```
DEPL_MULT_APPUI= (
             _F (NOM_CAS=' depl_S1_X',
                NUME_CAS=1,
                MODE_STAT=modstat,
                 NOEUD=' NS1',
                DX=U,
                ),
             _F (NOM_CAS=' depl_S2_X',
                NUME_CAS=2,
                MODE_STAT=modstat,
                 NOEUD=' NS2',
                DX=U,
                ),),
   COMB_DEPL_APPUI= (
      _F (
         LIST_CAS= (“1”, “2”),
         TYPE_COMBI =  ' LINE'
         ),
```

•Response by direction and total secondary office plurality

Let us consider one line anchored on 2 following $S1$ supports $S2$ and the seismic differential displacements:

•support $S1$: $U1$, $V1$ and $W1$ in the directions X, Y and Z
•support $S2$: $U2$, $V2$ and $W2$ in the directions X, Y and the Z

6 static modes of bearing are calculated beforehand.

The seizure of the various loading cases is carried out under the occurrences of DEPL_MULT_APPUI:

```
DEPL_MULT_APPUI= (
             #support S1 with node NS1
             _F (
                NOM_CAS=' depl_S1_X',
                NUME_CAS=1,
                MODE_STAT=modstat,
                 NOEUD=' NS1',
                DX=U1,
                ),
             _F (
                NOM_CAS=' depl_S1_Y',
                NUME_CAS=2,
                MODE_STAT=modstat,
                 NOEUD=' NS1',
                DY=V1,
                ),
             _F (
                NOM_CAS=' depl_S1_Z',
```

```
       NUME_CAS=3,
       MODE_STAT=modstat,
        NOEUD=' NS1',
       DZ=W1,
       ),
    #support S2 with node NS2
    _F (
       NOM_CAS=' depl_S2_X',
       NUME_CAS=4,
       MODE_STAT=modstat,
        NOEUD=' NS2',
       DX=U2,
       ),
    _F (
       NOM_CAS=' depl_S2_Y',
       NUME_CAS=5,
       MODE_STAT=modstat,
        NOEUD=' NS2',
       DY=V2,
       ),
    _F (
       NOM_CAS=' depl_S2_Z',
       NUME_CAS=6,
       MODE_STAT=modstat,
        NOEUD=' NS2',
       DZ=W2,
       ),
    ),
```

directional responses are established under the occurrences of `COMB_DEPL_APPUI` :

```
COMB_DEPL_APPUI= (
#cumul according to X
             _F (
                LIST_CAS= ("1", "4"),
                TYPE_COMBI =  ' QUAD',
                       ),
#cumul according to Y
             _F (
                LIST_CAS= ("2", "5"),
                TYPE_COMBI =  ' QUAD',
                       ),
#cumul according to Z
             _F (
                LIST_CAS= ("3", "6"),
                TYPE_COMBI =  ' QUAD',
                       ),
                ),
```

the secondary total response is formed by the quadratic office plurality of directional responses. It is calculated automatically.
If the printing of directional responses is not necessary, the total response can be calculated directly under only one occurrence of `COMB_DEPL_APPUI`:

```
COMB_DEPL_APPUI= (
#réponse total
             _F (
                TOUT=' OUI',
                TYPE_COMBI =  ' QUAD',
```

```
                    ),
```

3.9 Computation option: operand OPTION

♦OPTION

Lists quantities (computation options) modal which one wants to determine the combined response:

"DEPL"	displacement relative
"VITE"	relative velocity
"ACCE_ABSOLU"	absolute acceleration = relative acceleration + driving acceleration
"SIGM_ELNO"	forced by elements to nodes
"SIEF_ELGA"	forced by elements at the points of integration
"SIPO_ELNO"	forced in the section of beam broken up into contributions of each force generalized
"EFGE_ELNO"	forces generalized by elements to nodes
"REAC_NODA"	reactions to bearings
"FORC_NODA"	internal forces

3.10 Operand TITER

◊TITER = T

Titrates attached to the product concept by this operator [U4.03.01].

3.11 Operand INFO

◊INFO

/1: printing on the file "message" of following information:

- name of modal base used,
- many eigenvectors selected,
- modal combination rule chosen,
- computation options requested.

/2: idem 1

3.12 Key word PRINTING

◊IMPRESSION

Printing on the file "result" of following information:

/TOUT = "/NIVEAU
OUI' =

"SPEC_OSCI"	Values of the excitation corresponding to various modes
"MASS_EFFE"	quantities modal in the direction of the energization and office plurality of effective mass
"MAXI_GENE"	Contributions generalized maximum

With TOUT = "OUI', one obtains the printings corresponding to all the 3 levels defined above.

The printing in the file "result" of the computed fields is carried out via commands IMPR_RESU [U4.91.01] or POST_RELEVE_T [U4.81.21] by specifying the suitable sequence numbers.

For an excitation mono-bearing according to the 3 directions X, Y and Z:
•directional responses [§3.7]:
sequence numbers 1,2 and 3 for the responses according to X, Y and Z
•combination of directional responses if COMB_DIRECTION is present [§3.7.3]:
sequence number 4

For an excitation multi-bearing according to the 3 directions X, Y and Z:
•If key word COMB_DEPL_APPUI is absent, the primary and secondary components of the response are cumulated:
•directional responses [§3.8.1]:
sequence numbers 1,2 and 3 for the responses according to X, Y and Z
•combination of directional responses if COMB_DIRECTION is present [§3.7.3]:
sequence number 4
•If key word COMB_DEPL_APPUI is present, the primary and secondary components of the response are separate:
- primary component:
  •directional responses [§3.8.3]:
  sequence numbers 1,2 and 3 for the responses according to X, Y and Z
  •combination of directional responses if COMB_DIRECTION is present [§3.673]:
  secondary sequence number
- 4 component [§3.8.2]:
  •fields resulting from the combinations of loading cases of displacement indicated under N occurrences of COMB_DEPL_APPUI [§3.8.6]
  sequence number 200 for occurrence 1
  sequence number $200+i-1$ for the occurrence i
  sequence number $200+n-1$ for the quadratic n
  •occurrence office plurality total
  sequence number $200+n$

4 Concept in output

produced operator COMB_SISM_MODAL, for practical reasons of visualization, a concept of the type mode_ meca. However it is advisable to pay attention to the fact that result is not a mechanical eigen mode. In particular, one should not make postprocessing on this concept (cf paragraph 4.8 of Doc. [R4.05.03]).
In addition in parameter "FREQ", one stores the seismic number of direction, in accordance with paragraph 3.12:
1 ↔ direction X
2 ↔ direction Y
3 ↔ direction Z
formulates 4 ↔ office plurality on the directions (if required in computation

5)

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