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## Operator COMB\_SISM\_MODAL

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### 1 Goal

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To calculate a dynamic response to single or multiple imposed movements.

In the case of the multiple excitation, the supports are animated different movements for a given direction. These movements can be either correlated between them, or perfectly *décorrélés*. These requests are represented by spectra of answer of oscillator or SRO (for example of pseudo-acceleration) representing an earthquake or a shock, introduced in the form of tablecloth (spectra of oscillator depend on the value of reduced damping). These spectra of oscillator can be given starting from a *accélérogramme* of the seismic signal (real signal or synthetic signal) by the order `CALC_FONCTION` with the keyword factor `SPEC_OSCI` [U4.32.04].

The operator `COMB_SISM_MODAL` allows to determine, in any point of the structure, the maximum components of relative displacement, relative pseudovelocity, of absolute pseudo-acceleration, the maximum efforts generalized by element and the maximum reactions to the supports.

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

Product a concept of the type `mode_meca`.

## 2 Syntax

```

R [mode_stat] = COMB_SISM_MODAL

(
  ◆ MODE_MECA = mode [mode_meca]
  ◇ / TOUT_ORDRE = 'YES' [DEFECT]
  / NUME_ORDRE = l_ordre [l_I]
  / LIST_ORDRE = lordre [listis]
  / NUME_MODE = l_mode [l_I]
  / / FREQ = l_freq [l_R]
  / LIST_FREQ = lfreqr8 [listr8]
  ◇ PRECISION = / 1.D-3 [DEFECT]
  / prec [R]
  ◇ CRITERION = / 'RELATIVE' [DEFECT]
  / 'ABSOLUTE'

  ◇ MODE_CORR = acce [mode_stat_acce]
  ◇ FREQ_COUP = freq [R]

  ◆ / 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 = 'YES'
  / MULTI_APPUI='CORRELE'
  / MULTI_APPUI='DECORRELE'

  ◆ EXCIT =_F (◆ GROUP_NO = lgrno [l_gr_noeud]
    ◆ / ◆ AXIS = (c1, c2, c3) [l_R]
    ◆ SPEC_OSCI = spec [tablecloth]
    ◇ SCALE = echel [R]

    / ◆ TRI_AXE = (p1, p2, p3) [l_R]
    ◆ SPEC_OSCI = spec [tablecloth]
    ◇ SCALE = echel [R]

    / ◆ TRI_SPEC = 'YES' [KN]
    ◆ SPEC_OSCI= (spe1, spe2, spe3) [l_fonction]
    ◇ ECHELLE= (ech1, ech2, ech3) [l_R]

    ◇ NATURE = / 'ACCE' [DEFECT]
    / 'QUICKLY'
    / 'DEPL'
  )

  ◇ CORR_FREQ = / 'YES'
  / 'NOT' [DEFECT]

  ◆ COMB_MODE =_F ( ◆ / TYPE = / 'GUPTA'
  / 'SRSS'
  / 'CQC'
  / 'DPC'
  / 'ABS'
  / 'DSC'

  ◇ DURATION = S [R]
  ◇ FREQ_1 = Hz [R]
  ◇ FREQ_2 = Hz [R]
  )

```

```

    ◇ COMB_DIRECTION =_F (
        ◆ / TYPE = / 'QUAD'
        / 'NEWMARK'
    )

    ◇ COMB_MULT_APPUI =_F (
        ◆ / ALL = 'YES'
        / GROUP_NO =lgrno [l_gr_noeud]
        ◆ / TYPE_COMBI = / 'QUAD'
        / 'LINE'
    )

    ◇ GROUP_APPUI =_F (
        ◆ GROUP_NO =lgrno [l_gr_noeud]
    )

    ◇ DEPL_MULT_APPUI =_F (
        ◆ NOM_CAS = nomcas
        ◆ NUME_CAS = numcas
        ◇ GROUP_NO_REFE = lgrno [l_gr_noeud]
        ◆ MODE_STAT = stat [mode_stat_depl]
        ◆ GROUP_NO = lgrno [l_gr_noeud]
        ◆ | DX = dx [R]
        | DY = Dy [R]
        | DZ = dz [R]
    )

    ◇ COMB_DEPL_APPUI =_F (
        ◆ / ALL = 'YES'
        / LIST_CAS = list [l_ume]
        ◆ / TYPE_COMBI = / 'QUAD'
        / 'LINE'
        / 'ABS'
    )

    ◆ OPTION = | 'DEPL'
    | 'QUICKLY'
    | 'ACCE_ABSOLU'
    | 'SIGM_ELNO'
    | 'SIEF_ELGA'
    | 'SIPO_ELNO'
    | 'EFGE_ELNO'
    | 'REAC_NODA'
    | 'FORC_NODA'

    ◇ TITLE = tit [l_Kn]
    ◇ INFORMATION = / 1 [DEFECT]
    / 2
    ◇ =_F IMPRESSION ( / ALL = 'YES' [DEFECT]
        / LEVEL = | 'SPEC_OSCI'
        | 'MASS_EFFE'
        | 'MAXI_GENE'
    )
)

```

## 3 Operands

### 3.1 Definition of the clean modes of the structure

#### 3.1.1 Operand `MODE_MECA`

◆ `MODE_MECA = mode`

Name of the concept of the type `mode_meca` produced by the operator of modal analysis `CALC_MODES` [U4.52.02].

#### 3.1.2 Operands `TOUT_ORDRE` / `NUME_ORDRE` / `NUME_MODE` / `LISTE_ORDRE`

/ `TOUT_ORDRE = 'YES'`

Value by default which makes it possible to extract all the clean modes available in the concept `mode`.

/ `NUME_ORDRE = l_ordre`

/ `NUME_MODE = l_mode`

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

/ `LISTE_ORDRE = l_ordre`

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

#### 3.1.3 Operand `FREQ` / `LIST_FREQ` / `PRECISION` / `CRITERION`

/ `FREQ = l_freq`

Allows to extract the clean modes corresponding to a list from frequencies `l_freq`.

/ `LIST_FREQ = lfreqr8`

Allows to extract the clean modes corresponding to a list from frequencies `lfreqr8`, defined by the operator `DEFI_LIST_REEL` [U4.34.01] (`lfreqr8` is thus a concept of the type `listr8`).

◇ | `PRECISION = prec`

| `CRITERION =`

These operands make it possible to indicate that one searches all the clean modes whose frequency is in the interval  $inst \pm prec$ . By default  $prec = 1.0D-3$ .

According to the value of the keyword `CRITERION` :

'RELATIVE' : the interval of research is:

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

'ABSOLUTE' : the interval of research is:

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

### 3.2 Definition of modal depreciation

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

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## 3.2.1 Operand AMOR\_REDUIT

```
/ AMOR_REDUIT = amor
```

This operand makes it possible to provide the list of the depreciation reduced in the form of a list of realities (`l_r`). If the number of provided coefficients is lower than the numbers of clean 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 the depreciation reduced in the form of a concept of the type `listr8`. If the number of reduced depreciation is lower than the number of clean modes taken into account, the last coefficient is affected with the following modes.

### Example:

```
TOUT_ORDRE = 'YES'  
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 matrix of generalized damping `amogene` produced by the operator `PROJ_MATR_BASE` [U4.63.12] or `PROJ_BASE` [U4.63.11].

### Note:

*For theoretical reasons (tallies of `COMB_SISM_MODAL` restricted with "classical" damping) the matrix of damping must be **diagonal**.*

## 3.3 Operand MASS\_INER

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

This one is calculated by the order `POST_ELEM` [U4.81.22] with the keyword `MASS_INER`. The operand `MASS_INER` allows to provide the name of the concept produced by this order.

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

Three configurations are possible:

- the structure is studied with the same movement of training in all the supports;
- the structure is studied with several different movements of training to the supports, all correlated between them;
- the structure is studied with several different movements of training to the supports, whose one can display groups perfectly *décorrélés* between them, the excitations inside the same group of supports being supposed correlated between them.

### 3.4.1 Operand MONO\_APPUI

```
/ MONO_APPUI = 'YES'
```

The excitations all with the supports are equal.

## 3.4.2 Operand MULTI\_APPUI

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

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

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

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

## 3.5 Description of the excitation: keyword EXCIT

The seismic excitation is defined by one or more spectra of oscillators. Those are calculated as a preliminary by the order CALC\_FONCTION [U4.32.04] or read on a file by the order LIRE\_FONCTION [U4.32.02]. In both cases, the produced concept is of type `function` with two variables (`tablecloth`).

One uses for that the keyword factor

◆ EXCIT

and possibly the operand CORR\_FREQ.

### 3.5.1 Operand GROUP\_NO

One specifies with each occurrence of the keyword factor groups of nodes concerned with the described excitation.

### 3.5.2 Excitation along an axis

```
/ ◆ AXIS = (c1, c2, c3)  
◆ SPEC_OSCI = spec  
◇ SCALE = echel
```

In this case, one provides:

- the cosine directors  $(c1, c2, c3)$  axis of excitation in the reference mark `TOTAL` of definition of the grid: coefficients  $c1, c2, c3$  are renormés by the order,
- the operand `SPEC_OSCI` only one tablecloth of spectra of oscillator waits where `spec` is the name of the tablecloth to be used (spectra of oscillator depend on the value of reduced damping),
- the operand `SCALE` allows to define a scale factor `echel` to apply to all the points of the spectrum `spec`.

#### Example:

For an excitation with 45° compared to the reference mark `TOTAL`, a spectrum of ground `sol_0_1` fixed with 0.1 g and a scale factor allowing to simulate a spectrum fixed with 0.25 g :

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

### 3.5.3 Triaxial excitation with only one tablecloth of spectrum of oscillator

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

◇ SCALE = echel

In this case, one provides:

- weighting coefficients ( $p1 p2 p3$ ) to apply to the spectrum of oscillator of oscillator of pseudo-acceleration for each direction  $X$ ,  $Y$  and  $Z$ ,
- the operand SPEC\_OSCI only one tablecloth of spectra of oscillator (SRO) waits where *spec* is the name of the tablecloth to be used (spectra of oscillator depend on the value of reduced damping),
- the operand SCALE allows to define a scale factor *echel* to apply to all the points of the spectrum *spec*, independently of the weighting 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 ground fixed with  $0.1g$  and a scale factor allowing to simulate a spectrum fixed with  $0,25g$  :

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

### 3.5.4 Triaxial excitation with three tablecloths of different spectra of oscillator

```
/ ♦ TRI_SPEC = 'YES'  
♦ SPEC_OSCI = (spe1, spe2, spe3)  
◇ SCALE = (ech1, ech2, ech3)
```

In this case one provides:

- the operand TRI\_SPEC : 'YES',
- the operand SPEC\_OSCI expects three tablecloths of spectra of oscillators (spectra of oscillator depend on the value of reduced damping) where (*spe1 spe2 spe3*) is the list of the tablecloths to be used in are three directions  $X$ ,  $Y$ ,  $Z$ .
- the operand SCALE allows 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 size of the spectrum of oscillator. By default, one uses a spectrum of acceleration 'ACCE'. It is possible D' to more rarely use of other sizes: speed 'QUICKLY' or displacement 'DEPL'.

### 3.5.6 Operand CORR\_FREQ

◇ CORR\_FREQ

To calculate the components of answer of speed or in acceleration starting from a spectrum of oscillator of the size displacement ( $NATURE = 'DEPL'$ ), one is led to multiply each value one or twice by  $\omega_r$  pulsation of the real clean mode (oscillating not deadened). In any rigour the oscillator  $r$  is deadened and its own pulsation is  $\omega_r \sqrt{1-\xi^2}$  and  $\omega_r$  is only the own pseudo-pulsation. By default, one thus obtains:

$$\begin{aligned} vite_{max} &= \omega_r \text{depl}_{lu} = \text{pseudo-vitesse} \\ acce_{max} &= \omega_r^2 \text{depl}_{lu} = \text{pseudo-accelération} \end{aligned}$$

The operand CORR\_FREQ : 'YES' allows to correct these values to take into account the damping of the clean mode:

$$\begin{aligned} vite_{max} &= \omega_r \sqrt{1-\xi^2} \text{depl}_{lu} = \text{vitesse} \\ acce_{max} &= \omega_r^2 (1-\xi^2) \text{depl}_{lu} = \text{accélération} \end{aligned}$$

If one provides a spectrum of answer of speed (`NATURE = 'QUICKLY'`) the operand `CORR_FREQ` will be necessary to correct  $depl_{max}$  and  $acce_{max}$  if necessary. In the same way for a spectrum of answer 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 - size.

## 3.6 Rules of combination

To evaluate one raising of the answer of the structure, one reasons size by size (displacement, speed or acceleration, internal efforts, constraints) starting from the modal values associated with the clean modes taken into account. For each largeor, one will treat **independently** each degree of freedom (fields to the nodes of displacement, speed or acceleration), or each component of torque (internal efforts) or constraint. It is what we call the answer  $R$  in the statement of the rules of combination.

Several levels of combinations are necessary:

- combination of the clean modes,
- static correction by pseudo-mode,
- combination according to the directions of earthquake.

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

## 3.7 Rules of combination for an excitation mono-support

The answer **total** structure  $R$  is obtained by **combination of the directional answers**  $R_X$  where  $X$  represent one of the directions of the reference mark `TOTAL` of definition of the grid ( $X, Y, Z$ ) or a particular direction (cf operand `AXIS`). The directional answer is given by:

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

- $R_d$  dynamic combined answer of the modal oscillators established by the keyword `COMB_MODE` [§ 3.7.1]
- $R_t$  correction of the static effects of the neglected modes (pseudo-mode) [§ 3.7.2]
- $R_{qs}$  quasi-static combined answer of the modal oscillators established by the keyword `COMB_MODE` (`STANDARD = 'GUPTA'`) [§ 3.7.1.6]
- $R_e$  contribution of the movement of training ( $R_e = 0$  in mono-support)

The rule of combination of the directional answers is defined by the keyword `COMB_DIRECTION` [§ 3.6.3].

### 3.7.1 Combination of the clean modes: keyword `COMB_MODE`

#### ◆ `COMB_MODE`

The answer of the structure  $R_d$ , **in a direction of earthquake**, is obtained by one of the possible combinations (defined by the operand `TYPE`) contributions of each clean mode taken into account. Each clean mode is regarded as an oscillator independent of answer  $R_r$ , defined by  $(\omega_r, \xi_r)$ . The answer is read by interpolation in the spectrum of oscillator of the signal of excitation in this direction.



For an excitation mono-support, the answer  $R_r$  oscillator  $r$  is given by:

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

- $\Phi_r$  modal size (displacement, generalized effort, reaction) associated with the clean mode of index  $r$
- $P_r$  factor of modal participation associated with the mode  $r$  in the studied direction
- $S_r$  value of the spectrum of answer, for example in pseudo-acceleration, for the oscillator  $r$ , for the value of damping specified

Several rules of combination of the clean modes are available. They are chosen by the 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 clean mode:

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

Let us note that this rule of combination, although very usually used, can be badly adapted when the assumption of independence is not checked for nearby clean 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 clean 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:

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

### 3.7.1.3 Somme of the absolute values `TYPE = 'ABS'`

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

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

Let us note that this rule of combination 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 answers of the oscillators are combined by double nap (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, the duration  $s$  "strong" phase of the earthquake defined by the operand DURATION.

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

### 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 answer, introduced the rigid factor of answer, which varies from 0 to 1 the correlation between the modal answers of intermediate frequencies enters  $FREQ_1$  and  $FREQ_2$ , two frequencies to be determined by the user.

Gupta breaks up each modal answer  $R_r$  in a dynamic part  $R_r^p$  and a quasi-static part  $R_r^{qs}$  :

$$R_r^{qs} = \alpha_r R_r \text{ and } R_r^p = \sqrt{1 - \alpha_r^2} R_r$$

Thus, for each mode  $r$ , the rigid factor of answer is affected  $\alpha_r$  with the modal answer  $R_r$  :

$$\alpha_r = 0 \text{ for } f \leq f_1 \text{ and } \alpha_r = 1 \text{ for } f \geq f_2$$

$\alpha_r$  is 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 answer of the modal oscillators is carried out according to the 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 answer 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-support.

### 3.7.2 Static correction by pseudo-mode: operand `MODE_CORR`

The modal base used is in general incomplete. The evaluation of raising answer to a seismic excitation requires, so a correction by a term representing the static contribution of the neglected clean modes, in each direction of earthquake.

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

$$\mathbf{K}\varphi = \mathbf{M}\delta$$

- $\mathbf{K}$  matrix of rigidity of the structure
- $\mathbf{M}$  matrix of mass of the structure
- $\delta$  unit field in the direction of the earthquake

Pseudo-mode  $\Psi$  is obtained by withdrawing the static contributions of the modes taken into account:

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

- $\Phi_r$  clean mode of index  $r$
- $p_r$  factor of participation in the direction  $\delta$

In this direction  $\delta$ , for each size, the contribution of the neglected modes is given by:

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

$R_s$  is the size associated with the static mode

◇ `MODE_CORR = acce`

This keyword makes it possible to provide it (S) field (S) of displacements  $\varphi$  nodes of the structure subjected to a constant acceleration in one (or several) direction (S), field (S) calculated (S) by the operator `MODE_STATIQUE` with the keyword `PSEUDO_MODE` [U4.52.14]. For specific needs, it is also possible to provide a concept resulting from `CREA_RESU`, while choosing `TYPE_RESU=' MODE_MECA'` and by informing the keyword `AXIS` of `AFFE` to indicate the direction corresponding to each field (defines by its sequence number) [U4.44.12]. For any direction of earthquake where the answer is calculated, one calculates a pseudo-mode if `acce` is provided.

◇ `FREQ_COUP = fcoup`

This keyword makes it possible to provide the frequency where one will read on the SRO the value which will be used for the static level of correction. This frequency corresponds normally to the cut-off frequency of the seismic signal, i.e that where the SRO reached (in acceleration) an asymptote.

This key word is particularly useful when the last frequency of the modal base does not reach the cut-off frequency of the seismic signal although it is nevertheless sufficient to take into account all the dominating modes for the answer of the structure.

### 3.7.3 Combination according to the directions: keyword `COMB_DIRECTION`

◇ `COMB_DIRECTION`

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

### 3.7.3.1 Quadratic combination: `TYPE = 'QUAD'`

This combination corresponds to the assumption of strict independence of the answers 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  $i(X, Y, Z)$ , the 8 values are calculated:

$$R_i = \pm R_x \pm 0,4 R_y \pm 0,4 R_z$$

What leads, by circular shift, with 24 values and

$$R = \max(R_i)$$

## 3.8 Case of an excitation multi-support

Two treatments are envisaged [feeding-bottle 3]:

- Calculation of the total answer
- Calculation of the primary and secondary components of the answer

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

- that is to say these movements all are correlated between them (case correlated excitations),
- either one can display at least 2 groups of perfectly décorrélés supports, the supports constitutive of the same group being correlated between them (case décorréléés excitations).

### 3.8.1 Calculation of the total answer

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

#### 3.8.1.1 Correlated excitations

- For each mode of index  $j$ , the modal directional answers are calculated  $R_{Xj}$  by combination of the modal directional answers of support  $R_{Xij}$ . The rule of combination is defined by the keyword `COMB_MULT_APPUI` [§ 3.8.3].
- The directional answers are calculated  $R_X$  defined by:
$$R_X = \sqrt{R_{Xd}^2 + R_{Xi}^2 + R_{Xe}^2}$$
  - $R_{Xd}$  is the combined answer of the modal directional answers established by the keyword `COMB_MODE` [§ 3.7.1];
  - $R_{Xi}$  represent the static correction of the neglected modes. This term is obtained by algebraic office plurality of the pseudo-modes of support;
  - $R_{Xe}$  represent the movement of training. This term is obtained by algebraic combination of the movements of training of support.
- The total answer  $R$  structure is obtained by combination of the directional answers  $R_X$ . The rule of combination is defined by the keyword `COMB_DIRECTION` [§ 3.7.3].

## 3.8.1.2 Décorrélées excitations

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

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

- $R_{Xdi}$  is the combined answer of the modal oscillators established by the keyword `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-support. Similar but is calculated to intervene the field of displacements of the structure subjected to a unit acceleration of support  $i$  in direction  $X$  [bib3];
- $R_{Xei}$  is the contribution of the movement of training of the support  $i$  ( $R_{ei} \neq 0$  in multi-support) established by the keyword `DEPL_MULT_APPUI` [§ 3.8.5].
- The directional answers are calculated  $R_X$  by combination of the directional answers of supports  $R_{Xi}$ . The groups of supports being supposed décorrélés between them, the directional answers of supports are combined quadratically (not choice left to the user).
- The total answer  $R$  structure is obtained by combination of the directional answers  $R_X$ . The rule of combination is defined by the keyword `COMB_DIRECTION` [§ 3.7.3].

## 3.8.2 Partition of the components primary and secondary of the answer

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

### 3.8.2.1 Inertial primary component

It is the inertial answer induced by the accelerations imposed on anchorings (SRO). One renews the treatment adopted for the total answer by removing the contribution of the movement of training. The order of the combinations to be carried out differs according to whether the excitations of the supports all are correlated between them or that they set up groups décorrélés between them.

- Correlated supports
  - For each modal oscillator  $j$ , the modal directional answers are calculated (office plurality on the supports)  $R_{IXj} = \sqrt{R_{dj}^2 + R_{tj}^2}$  with:
    - $R_{dj}$  combined modal answer of the modal oscillators (office plurality on the supports). The rule of combination is defined by the keyword `COMB_MULT_APPUI` [§ 3.8.3].
    - $R_{tj}$  contribution of the static correction of the neglected modes (pseudo-mode of support)
  - The directional answers are calculated  $R_{IX}$  by combination of the modal directional answers  $R_{IXj}$ , using the keyword `COMB_MODE` [§ 3.7.1].
- Décorrélés groups of supports
  - One defines the possible groups of supports using the keyword `GROUP_APPUI`. The answers of the modal oscillators of the same group of supports are combined linearly (not choice left to the user for this office plurality intra-group).

- For each support or groups supports subscribed by  $i$ , subjected to a different excitation, one calculates the directional answers of primary education supports  $R_{IXi}$  defined by:

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

- $R_{di}$  combined answer of the modal oscillators established by the keyword COMB\_MODE [§ 3.7.1]
- $R_{ii}$  represent the correction of the static effects of the neglected modes. The term differs from the case mono-support. Similar but is calculated to intervene the field of displacements of the structure subjected to a unit acceleration of support I in direction X [bib3].
- The directional answers are calculated  $R_{IX}$  by combination of the directional answers of supports  $R_{IXi}$ . The groups of supports being supposed décorrélés between them, the directional answers of supports are combined quadratically (not choice left to the user).

The primary total answer  $R_I$  structure is obtained by combination of the directional answers  $R_{IX}$ . The rule of combination is defined by the keyword COMB\_DIRECTION [§ 3.7.3].

### 3.8.2.2 Differential secondary component

It is the static answer induced by seismic differential displacements of anchorings (movement of training):

- Calculation of the contribution  $R_{ei}$  movement of training of the support  $i$  established by the keyword DEPL\_MULT\_APPUI [§ 3.8.5]
- Combinations of the various definite contributions of support  $R_{ei}$  by the keyword COMB\_DEPL\_APPUI [§ 3.8.6].

It is thus possible to reconstitute:

- lawful loading cases corresponding to:
  - an overall movement of part of the supports in a given direction
  - a displacement mentioned in a local reference mark different from the total reference mark of inertial seismic request;
- directional answers by combining the adequate contributions of supports;
- the total secondary answer.

Examples are proposed in [§ 3.8.6.6].

### 3.8.3 Keyword COMB\_MULT\_APPUI (case MULTI\_APPUI=CORRELE)

◇ COMB\_MULT\_APPUI

The occurrences of this key word make it possible to define:

- combinations of the modal directional answers of support to form the modal directional answers (case of the correlated excitations);
- combinations of the directional answers of support to form the directional answers structure (case of the décorrélées excitations).

If occurrences of the key word COMB\_MULT\_APPUI is present, it is the primary component of the answer which is treated.

The combination of the contributions of each movement of support can be combined various manners, defined by the operand TYPE\_COMBI :

- quadratic combination
- linear combination

### 3.8.3.1 Operands ALL/GROUP\_NO

◆ / ALL = 'YES'

Allows to choose that all the supports are combined with the rule defined by TYPE

/ GROUP\_NO = lgrno [l\_group\_no]

Allows to define the list of the supports which are combined with the rule defined by the operand TYPE\_COMBI in the same occurrence of the keyword 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 the movements of support are décorrélés.

### 3.8.3.3 Linear combination TYPE = 'LINE'

$$R_x = \sum R_{xk}$$

### 3.8.3.4 Different rules of combination on the various supports

The rule of combination can be the same one for all the supports [§ 3.7.3.1] or differentiated according to the supports or groups of supports defined by an occurrence of the keyword factor COMB\_MULT\_APPUI. In this case the total answer - or the primary component of the answer if COMB\_DEPL\_APPUI is present - is obtained by:

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

where  $j$  indicate the supports combined quadratically and  $k$  linearly combined supports.

## 3.8.4 Keyword GROUP\_APPUI (case MULTI\_APPUI=DECORRELE )

◇ GROUP\_APPUI

If this keyword is absent, all the supports are regarded as décorrélés between them.

This keyword is used only if one can display one or more groups of supports décorrélés between them, the supports constitutive of a group being correlated between them. A group can be made up of only one support.

The occurrences of this keyword make it possible to define the groups of supports. The supports not belonging to a group are regarded as décorrélés between them and décorrélés of the definite groups.

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

### 3.8.4.1 Operands ALL / GROUP\_NO

◆ GROUP\_NO = lgrno [l\_group\_no]

Allows to define the list of the groups of supports.

## 3.8.5 Keyword DEPL\_MULT\_APPUI

◇ DEPL\_MULT\_APPUI

The movement of training of the structure not being uniform this keyword makes it possible to define the contribution to the total answer of a list of supports or groups of supports. This one is established starting from the static modes of the structure:

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

with:

- $\Phi_{si}$  static mode for the support  $i$
- $\delta_{i\max}$  maximum displacement of the support  $i$  compared to a support of reference (for which  $\delta_{i\max} = 0$ )

If this keyword is not indicated, then the contribution of the static modes of the structure is worthless. In other words, this is equivalent to inform  $\delta_{i\max} = 0$ .

### 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  $\Phi_{si}$ , concept of the type mode\_stat product by the operator MODE\_STATIQUE [U4.52.14].

### 3.8.5.3 Operand GROUP\_NO\_REFE

- ◇ GROUP\_NO\_REFE = grno  
Group containing Nœud of reference by report to which relative displacements of the supports are defined (group given should contain one node).  
If this operand is present, the maximum displacement applied to the support  $i$  is worth  $\delta_{i\max} - \Delta$  where  $\Delta$  is affected displacement with node of reference noeui in the direction considered.

### 3.8.5.4 Operand GROUP\_NO

- ◆ GROUP\_NO = lgrno  
List of the names of S groups of nodes corresponding to the supports concerned with the occurrence of the keyword factor DEPL\_MULT\_APPUI.

### 3.8.5.5 Operands DX / DY / DZ

- ◆ | DX = dx  
| DY = dy  
| DZ = dz  
Value of maximum relative displacement of the supports concerned, direction by direction.

## 3.8.6 Keyword COMB\_DEPL\_APPUI

- ◇ COMB\_DEPL\_APPUI



The occurrences of this key word define the combinations of the lawful loading cases intervening in the secondary component of the answer.

### 3.8.6.1 Operands ALL/LISTE\_CAS

- ◆ / ALL = 'YES'  
All 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 TYPE

### 3.8.6.2 Quadratic combination TYPE = 'QUAD'

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

### 3.8.6.3 Linear combination TYPE = 'LINE'

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

### 3.8.6.4 Combination in absolute value TYPE = 'ABS'

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

### 3.8.6.5 Different rules of combination on the various loading cases

The rule of combination can be the same one for all the cases of displacement of anchoring or differentiated according to the groups of cases defined by an occurrence of the keyword factor COMB\_DEPL\_APPUI. In this case the secondary total answer is obtained by:

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

where  $j$  indicate the supports combined quadratically,  $k$  linearly combined supports and  $l$  supports combined in absolute value.

### 3.8.6.6 Examples of application

- Displacement expressed in a local reference mark  $R_{loc}(x, y, z)$  different from the total reference mark  $R_{glob}(X, Y, Z)$

Axes  $x$ ,  $y$  and  $z$  of  $R_{loc}$  are built by 3 successive rotations of angle  $\alpha$ ,  $\beta$  and  $\gamma$  around the axes  $X$ ,  $Y$  and  $Z$  of  $R_{glob}$ .

To simplify the example, it is considered that  $R_{loc}$  results from  $R_{glob}$  by a single rotation around the axis  $X$  and of angle  $\alpha$  and that local displacement  $u_x$  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  $DX = u_x \cos \alpha \text{depl } X$  along the axis  $X$
- displacement  $DY = u_x \sin \alpha \text{depl } Y$  along the axis  $Y$

Static modes of support 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,  
    GROUP_NO= 'GNS',  
    DX=deplX,  
  ),  
  _F (  
    NOM_CAS=' uxsin',  
    NUME_CAS=2,  
    MODE_STAT=modstat,  
    GROUP_NO= 'GNS',  
    DY=deplY,  
  ),  
) ,  
COMB_DEPL_APPUI= (  
  _F (  
    LIST_CAS= ('1', '2'),  
    TYPE_COMBI = 'LINE'  
  ),  
) ,
```

- Overall movement in a direction

Let us consider a line anchored on 3 supports  $S1$ ,  $S2$  and  $S3$ . An overall movement  $U$  is applied to the supports  $S1$ ,  $S2$  in the direction  $X$ . The support  $S3$  dependent on the crossing of a building is supposed to be fixed.

Static modes of support 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,  
    GROUP_NO= 'GNS1',  
    DX=U,  
  ),  
  _F (NOM_CAS=' depl_S2_X',  
    NUME_CAS=2,  
    MODE_STAT=modstat,  
    GROUP_NO= 'GNS2',  
    DX=U,  
  ),  
) ,  
COMB_DEPL_APPUI= (  
  _F (  
    LIST_CAS= ('1', '2'),  
    TYPE_COMBI = 'LINE'  
  ),  
) ,
```

- Answer by direction and total secondary office plurality

Let us consider a line anchored on 2 supports  $S1$  and  $S2$  and following 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  $Z$

The 6 static modes of support 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,  
    GROUP_NO= 'GNS1',  
    DX=U1,  
  ),  
  _F (  
    NOM_CAS=' depl_S1_Y',  
    NUME_CAS=2,  
    MODE_STAT=modstat,  
    GROUP_NO= 'GNS2',  
    DY=V1,  
  ),  
  _F (  
    NOM_CAS=' depl_S1_Z',  
    NUME_CAS=3,  
    MODE_STAT=modstat,  
    GROUP_NO= 'GNS1',  
    DZ=W1,  
  ),  
  #support S2 with node NS2  
  _F (  
    NOM_CAS=' depl_S2_X',  
    NUME_CAS=4,  
    MODE_STAT=modstat,  
    GROUP_NO= 'GNS2',  
    DX=U2,  
  ),  
  _F (  
    NOM_CAS=' depl_S2_Y',  
    NUME_CAS=5,  
    MODE_STAT=modstat,  
    GROUP_NO= 'GNS2',  
    DY=V2,  
  ),  
  _F (  
    NOM_CAS=' depl_S2_Z',  
    NUME_CAS=6,  
    MODE_STAT=modstat,  
    GROUP_NO= 'GNS2',  
    DZ=W2,  
  ),  
)
```

The directional answers 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 answer is formed by the quadratic office plurality of the directional answers. It is calculated automatically.

If the impression of the directional answers is not necessary, the total answer 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 Option of calculation: operand OPTION

### ◆ OPTION

List of the sizes (options of calculation) modal which one wants to determine the combined answer:

'DEPL'	relative displacement
'QUICKLY'	relative speed
'ACCE_ABSOLU'	absolute acceleration = relative acceleration + acceleration of training
'SIGM_ELNO'	constraints by elements with the nodes
'SIEF_ELGA'	constraints by elements at the points of integration
'SIPO_ELNO'	constraints in the section of beam broken up into contributions of each generalized effort
'EFGE_ELNO'	efforts generalized by elements with the nodes
'REAC_NODA'	reactions to the supports
'FORC_NODA'	internal efforts

### Note:

For the calculation of the options of efforts or constraints on part of the model defined by groups of meshes, it is possible to connect a calculation on the concept mode produced by the operator CALC\_CHAMP.

## 3.10 Operand TITLE

### ◆ TITLE = T

Title attached to the concept produced by this operator [U4.03.01].

## 3.11 Operand INFORMATION

### ◆ INFORMATION

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

- name of the modal base used,
- many clean vectors selected,
- rule of modal combination chosen,
- options of calculation requested.

/2: idem 1

## 3.12 Keyword IMPRESSION

◇ IMPRESSION

Impression on the file "result" of following information:

```
/ ALL = 'YES'  
/ LEVEL =
```

'SPEC_OSCI'	values of the excitation corresponding to the various modes
'MASS_EFFE'	modal sizes in the direction of the excitation and office plurality of the effective mass
'MAXI_GENE'	maximum generalized contributions

With ALL = 'YES', one obtains the impressions corresponding to the whole of the 3 levels defined above.

The impression in the file "result" of the computed fields is carried out via the orders IMPR\_RESU [U4.91.01] or POST\_RELEVE\_T [U4.81.21] by specifying the suitable sequence numbers.

For an excitation mono-support according to the 3 directions  $X$ ,  $Y$  and  $Z$  :

- directional answers [§3.7]:  
sequence numbers 1.2 and 3 for the answers according to  $X$ ,  $Y$  and  $Z$
- combination of the directional answers if COMB\_DIRECTION is present [§3.7.3]:  
sequence number 4

For an excitation multi-support according to the 3 directions  $X$ ,  $Y$  and  $Z$  :

- If the keyword COMB\_DEPL\_APPUI is absent, the components primary and secondary of the answer are cumulated:
  - directional answers [§3.8.1]:  
sequence numbers 1.2 and 3 for the answers according to  $X$ ,  $Y$  and  $Z$
  - combination of the directional answers if COMB\_DIRECTION is present [§3.7.3]:  
sequence number 4
- If the keyword COMB\_DEPL\_APPUI is present, the components primary and secondary of the answer are separate:
  - primary component:
    - directional answers [§3.8.3]:  
sequence numbers 1.2 and 3 for the answers according to  $X$ ,  $Y$  and  $Z$
    - combination of the directional answers if COMB\_DIRECTION is present [§3.673]:  
sequence number 4
  - secondary component [§3.8.2]:
    - fields resulting from the combinations of loading case of displacement indicated under N occurrences from 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 occurrence  $n$   
total quadratic office plurality  
sequence number  $200 + n$

## 4 Concept at exit

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The operator `COMB_SISM_MODAL` product, for practical reasons of visualization, a concept of the type `mode_meca`. However it is advisable to pay attention to the fact that the result is not a mechanical clean mode. In particular, one should not make postprocessing on this concept (cf paragraph 4.8 of Doc. [R4.05.03]).

In addition in the parameter 'FREQ', one stores the seismic number of direction, in accordance with paragraph 3.12:

- 1 ↔ direction  $X$
- 2 ↔ direction  $Y$
- 3 ↔ direction  $Z$
- 4 ↔ office plurality on the directions (if asked in calculation)

## 5 Bibliography

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