Code_Aster

Titre : Opérateur CALC_AMOR_MODAL
Responsable : DEVESA Georges

Version
default

Date : 24/07/2015 *Page : 1/7*
Clé : U4.52.13 *Révision* :
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Operator `CALC_AMOR_MODAL`

1 Goal

To create a list of modal depreciation calculated according to the rule of the RCC-G. Calculation is carried out in postprocessing of the modal calculation of a structure of type building whose foundation raft rests on a ground modelled by springs.

The principle of calculation is based on weighting by the rates of potential energy (compared to total energy) of the reduced depreciation affected by groups of meshs constitutive of the structure (by way of parameters of entry of the table of potential energy created by `POST_ELEM`) and of the depreciation radiated in the ground, by degree of freedom, functions of the frequency [bib1] [bib2].

There is also the alternative possibility to directly create a list of modal depreciation by calculated frequency of a concept of the type `mode_meca`. This list depends at the same time on the values of the frequencies on the mode and coefficients intervening in the expression of the damping of Rayleigh.

The list created is usable thereafter in the order `DYNA_TRAN_MODAL` [U4.53.21] behind the keyword `LIST_AMOR`.

Product a concept of the type `listr8`.

Code_Aster

Titre : Opérateur CALC_AMOR_MODAL
Responsable : DEVESA Georges

Version
default

Date : 24/07/2015 Page : 2/7
Clé : U4.52.13 Révision :
5a9a3a0716c0

2   Syntax

```
listr8 [listr8] =  CALC_AMOR_MODAL (

/  ♦  ENER_SOL = _F ( ♦  MODE_MECA =  MOD,              [mode_meca]
                    ◊   METHOD =  /  'DEPL',            [DEFECT]
                                  /  'RIGI_PARASOL',
                    ♦   KX     =  kx,                   [R]
                    ♦   KY     =  ky,                   [R]
                    ♦   KZ     =  kz,                   [R]
                    ◊  ♦  KRX     =  krx,               [R]
                       ♦  KRY     =  kry,               [R]
                       ♦  KRZ     =  krz,               [R]

              # If METHODE=' DEPL':
                    ♦   GROUP_NO_RADIER = l_grno,       [l_group_no]

              # If METHODE=' RIGI_PARASOL':
                    ♦  GROUP_MA_RADIER = l_grma,        [l_group_ma]
                    ♦  /  FONC_GROUP     = l_fonc,      [l_fonction]
                       /  COEF_GROUP     = l_coef,      [l_R]
                    ♦  /  GROUP_NO_CENTRE = grno,       [group_noeud]
                       /  NOEUD_CENTRE    = node,       [node]
                       /  COOR_CENTRE     = (X, there, Z),    [l_R]
                    ),
   ♦  AMOR_INTERNE = _F  (
                    ♦   ENER_POT     = epot,            [table_sdaster]
                    ♦   GROUP_MA     = l_grma,          [l_group_ma]
                    ♦   AMOR_REDUIT  = l_amor,          [l_R]
                    ),
   ♦  AMOR_SOL  = _F  (
                    ◊   AMOR_REDUIT =   / 0. ,          [DEFECT]
                                       / amor,         [R]
                    ♦  FONC_AMOR_GEO = l_f_amor,        [l_fonction]
                    ◊  HOMOGENEOUS    =   / 'YES',       [DEFECT]
                                         / 'NOT',
                    ◊   THRESHOLD        =    / 0.3,        [DEFECT]
                                       / threshold,     [R]
                    ),
/  ♦  AMOR_RAYLEIGH   = _F ( ♦  MODE_MECA =  MOD,       [mode_meca]
                    ♦  AMOR_ALPHA   =  alpha,           [R]
                    ♦  AMOR_BETA    =  beta,            [R]
                       ),
                                      )
```

Code_Aster

Titre : Opérateur CALC_AMOR_MODAL
Responsable : DEVESA Georges

Version default

Date : 24/07/2015 *Page : 3/7*
Clé : U4.52.13 *Révision* :
5a9a3a0716c0

3 Operands

3.1 Keyword ENER_SOL

This keyword factor used only once serves to introduce the data necessary to calculation of the potential energy into the ground per degree of freedom for all the frequencies as a concept of the type `mode_meca`.

3.1.1 Operand METHOD

This operand makes it possible to define the method of calculating of energy in the ground by frequency.

With the value 'DEPL', one calculates energy starting from the displacements realised on the nodes of the foundation raft for each mode: $E = \frac{1}{2} \sum_{i=1,6} k_i U_i^2 (fr)_i$, where them k_i the 6 components represent KX, KY, KZ, KRX, KRY and KRZ total rigidity within the competences of ground (cf [§3.1.3]).

With the value 'RIGI_PARASOL', one calculates energy starting from the efforts realised on the nodes of the foundation raft for each mode: $E = \frac{1}{2} \sum_{i=1,6} \frac{F_i^2}{k_i} (fr)_i$.

The efforts with the nodes with this method are given starting from the values of rigidity distributed with the nodes under the foundation raft as by the option RIGI_PARASOL order AFFE_CARA_ELEM [U4.42.01].

3.1.2 Operand MODE_MECA

Allows to introduce the concept of the type `mode_meca` containing the frequencies of calculation of the potential energy.

3.1.3 Operands KX / KY / KZ / KRX / KRY / KRZ

The values of the components of the total rigidity within the competences of ground represent.

Intervene in the calculation of the terms $k_i . U_i^2, i = 1, NCmp$,

$NCmp$ is the component count (3 or 6) determined by the presence or the absence of the operands KRX, KRY, KRZ used (if they are it) obligatorily together. $NCmp$ and the number of ddls increased by the nodes of the foundation raft can be different.

3.1.4 Operand GROUP_NO_RADIER

This operand is related to the value 'DEPL' operand METHOD.

List of groups of nodes constituting the foundation raft of the structure posed on the ground. One calculates thereafter the displacement realised in these nodes U components U_i for each calculated mode of frequency fr in order to be able to determine energy in the ground by ddl and frequency: $\frac{1}{2} k_i . U_i^2 (fr)$.

3.1.5 Operand GROUP_MA_RADIER

This operand is related to the value 'RIGI_PARASOL' operand METHOD.

Code_Aster

Titre : Opérateur CALC_AMOR_MODAL
Responsable : DEVESA Georges

Version
default

Date : 24/07/2015 Page : 4/7
Clé : U4.52.13   Révision   :
                  5a9a3a0716c0

List of groups of meshs constituting the foundation raft of the structure posed on the ground. Allows to calculate the effort realised with the nodes of these meshs F components F_i for each calculated mode of frequency fr in order to determine energy in the ground by ddl and frequency: $\dfrac{1}{2}\dfrac{F_i^2}{k_i}(fr)$.

3.1.6 Operand `FONC_GROUP` / `COEF_GROUP` / `GROUP_NO_CENTRE` / `NOEUD_CENTRE` / `COOR_CENTRE`

These operands are also related to the value 'RIGI_PARASOL' operand METHOD.

These are the same ones as in the option RIGI_PARASOL order AFFE_CARA_ELEM [U4.42.01]. They also make it possible to obtain the values of rigidity distributed with the nodes under the foundation raft being used to determine the nodal efforts by mode then their average F of component F_i.

An operand chosen among FONC_GROUP / COEF_GROUP allows to determine weightings, real functions of the X-coordinate or, each group of meshs constitutive of the foundation raft. The formulas remain with the choice of the user. By default, one considers that the function of distribution is constant and unit, i.e. that each surface is affected same weight [bib2].

One thus needs as many terms in the corresponding list than in the list of the groups of meshs given by the operand GROUP_MA_RADIER.

An operand chosen among GROUP_NO_CENTRE / NOEUD_CENTRE / COOR_CENTRE allows to provide either the central node of the foundation raft by a group of nodes of only one name or by a single name of node, or directly its coordinates.

3.2 Keyword `AMOR_INTERNE`

Used only once at the same time as the keyword ENER_SOL.

The contribution to the reduced damping of each mode is established starting from the distribution of the potential energy in the structure for the mode considered. This distribution is obtained using the order POST_ELEM [U4.81.22] starting from the concept of the type mode_meca (cf [§3.1.1]) which produces a table.

The parameters of entry of this table are names of groups of meshs, defined by the user according to the distributions of material damping in the structure.

3.2.1 Operand `ENER_POT`

Name of the table of potential energy produced by the order POST_ELEM [U4.81.22].
The parameters necessary of the table are:

Parameters	Type	Description
NUME_ORDRE	I	Sequence number
FREQ	R	Frequency with the sequence number NUME_ORDRE
PLACE	K8	Associated geometrical entity: they can be all the structure, a set of meshs or groups of meshs
POUR_CENT	R	Rate of potential energy compared to total energy

For more information on the direction of the parameters, the reader is invited to consult the documentation of the order POST_ELEM [U4.81.22].

3.2.2 Operand `GROUP_MA`

Code_Aster

Titre : Opérateur CALC_AMOR_MODAL
Responsable : DEVESA Georges

Version default

Date : 24/07/2015 Page : 5/7
Clé : U4.52.13 Révision :
5a9a3a0716c0

The list of names of groups of meshs from which one will point in the table defined by ENER_POT (cf [§3.2.1]).

It is imperative that this list contains all the groups of meshs constitutive of the structure and that those had well their energy calculated in the table defined by ENER_POT. It will be considered that for each mode the sum of energies passing by the preceding groups of meshs will be equal to energy total minus that passing by the springs of ground and distributed starting from the keyword ENER_SOL. If the user indicates a name of group of meshs whose energy was not calculated in the table defined by ENER_POT, it will have an alarm but not stop. It is thus well with him to check the conformity of the groups of meshs of the table and those of the list in the keyword AMOR_INTERNE.

Lastly, so that the calculation of the list of modal depreciation according to the rule of the RCC-G has a direction, so that in particular energy passing by the springs of ground is not negative (what would imply that the rate of potential energy of the whole of the groups of meshs constitutive of the structure could exceed 100%), it is strongly advised to impose a solid condition of connection on the list of groups of nodes constituting the foundation raft of the structure posed on the ground.

3.2.3 Operand AMOR_REDUIT

The list of the actual values of material damping corresponding, term for term, with the list of names of groups of meshs defined by GROUP_MA (cf [§3.2.2]).

3.3 Keyword AMOR_SOL

Used only once at the same time as the keyword ENER_SOL.

It makes it possible to determine the contribution of geometrical damping due to the reflection of the elastic waves. These directional values of damping are obtained by interpolating for each calculated Eigen frequency the geometrical functions of damping $\dfrac{\mathrm{Im}(K(\omega))}{2\,\mathrm{Re}(K(\omega))}$ (cf § [3.3.1]) where $K(\omega)$ is the complex impedance of the ground determined using one of the software MISS3D, CLASSI or PARASOL:

$$amor(\omega_i) = \left[\omega_i, \frac{\mathrm{Im}(K(\omega_i))}{2\,\mathrm{Re}(K(\omega_i))}\right]$$

3.3.1 Operand FONC_AMOR_GEO

The list of functions of the frequency of geometrical depreciation, one by ddl defines (3 or 6).

3.3.2 Operand AMOR_REDUIT

Correction in the calculation of geometrical damping due to the reduced material damping of the ground.

> **Note:**
>
> *The value of reduced damping is necessary if the impedance of the ground is produced by PARASOL. One then affects the complete value of the reduced material damping of the ground. If the impedance of the ground is produced by MISS3D, this value is necessary only if the ground is homogeneous (see operand HOMOGENEOUS [§3.3.3]) and into this case one introduces the half-value of the reduced material damping of the ground.*

3.3.3 Operand HOMOGENEOUS

Code_Aster

Titre : Opérateur CALC_AMOR_MODAL
Responsable : DEVESA Georges

Version
default

Date : 24/07/2015 Page : 6/7
Clé : U4.52.13   Révision   :
5a9a3a0716c0

If the ground is homogeneous ('YES'), one balances the calculation of geometrical damping by factor 0.5. Then if the impedance of the ground is produced by MISS3D and only if the ground is homogeneous ('YES'), one must introduce for the operand AMOR_REDUIT (cf [§3.3.2]) the half-value of the reduced material damping of the ground. Nothing is introduced when the impedance of the ground is produced by MISS3D if the ground is not homogeneous ('NOT').

3.3.4 Operand THRESHOLD

Value defined in the RCC-G [bib1] (0.3 by default) for the threshold beyond which one truncates possibly modal damping. This threshold operates after the possible preceding corrections.

3.4 Keyword AMOR_RAYLEIGH

Used only once other than the keyword ENER_SOL. This keyword makes it possible to calculate a list of damping modal by calculated frequency of a concept of the type mode_meca. This list depends at the same time on the values of the frequencies of the mode $freq_i$ and of the coefficients intervening in the expression of the damping of Rayleigh.

3.4.1 Operand MODE_MECA

Allows to introduce the concept of the type mode_meca containing the frequencies from which one will calculate modal damping.

3.4.2 Operands AMOR_ALPHA / AMOR_BETA

The values of the components represent respectively α and β intervening in the expression of the damping of Rayleigh starting from the operators of rigidity and mass: $C = \alpha K + \beta M$.
Then for each calculated frequency $freq_i$ concept of the type mode_meca mod associated with a pulsation $\omega_i = 2\pi freq_i$ one obtains a modal damping are equivalent:

$$\xi_i = \frac{1}{2}(\alpha\omega_i + \frac{\beta}{\omega_i})$$

4 Bibliography

(1) RCC-G: Rules of design and construction of the nuclear islands REFERENCE MARK. EDF - Direction of the Equipment Edition July 1988

(2) Fe. Seismic WAECKEL Answer by transitory analysis [R4.05.01]

Code_Aster

Titre : Opérateur CALC_AMOR_MODAL
Responsable : DEVESA Georges

Version
default

Date : 24/07/2015 Page : 7/7
Clé : U4.52.13   Révision   :
5a9a3a0716c0

5   Example of use

The use of CALC_AMOR_MODAL require the calculation of the clean modes of the structure on springs of ground in the form of a concept of the type mode_meca and of a concept of the type table_sdaster of these modes calculated by means of the order POST_ELEM [U4.61.04].

The following example is extracted from test SDLL109B.

```
# CALCULATION OF THE MODAL QUANTITIES
-----------------------------------------

MODE0=CALC_MODES (MATR_RIGI=RIGIDITE,
                  MATR_MASS=MASSE,
                  OPTION = 'PLUS_PETITE',
                  CALC_FREQ=_F (NMAX_FREQ = 33),
                  SOLVEUR_MODAL=_F (DIM_SOUS_ESPACE = 125))

MODE0=NORM_MODE (reuse=MODE0,  MODE=MODE0,
                 NORME=' TRAN_ROTA',
                 MASS_INER=MASSESTR)

EPOT=POST_ELEM (MODELE=STICKMOD,
                RESULTAT=MODE0,
                CHAM_MATER=CHAMPMAT,
                CARA_ELEM=CARA_ELE,
                MASS_INER= (_F (GROUP_MA= ('MASSES', 'LIAI_SOL', 'LIAI_NOE',
                                           'POU_D_T',),),
                            _F (TOUT=' OUI',),),),)
#
FT=DEFI_FONCTION (NOM_PARA=' FREQ',
                  VALE= (0. , 0.0,  10. , 0.3,30. , 1.5,100. , 1.5,))

#
FR=DEFI_FONCTION (NOM_PARA=' FREQ',
                  VALE= (0. , 0.0,  10. , 0.05,30. , 0.75,100. , 0.75,))

L_AMOR=CALC_AMOR_MODAL (
        ENER_SOL=_F (MODE_MECA = MODE0,
                     GROUP_NO_RADIER = 'P1',
                     KX = 6.295E11, KY = 6.295E11, KZ = 6.864E11,
                     KRX = 3.188E14, KRY = 3.188E14, KRZ = 3.2E14),
        AMOR_INTERNE=_F (
            ENER_POT = EPOT,
            GROUP_MA = ('POU_D_T', 'MASSES', 'LIAI_NOE',),
            AMOR_REDUIT = (0.07, 0.07,0.02,)),
        AMOR_SOL=_F (
            FONC_AMOR_GEO = (FT, FT, FT, FR, FR, FR,),
            HOMOGENEOUS = 'NOT')
                        )
```