SDNX101 - Checking of chaining MISS3D -*Code_Aster* for the dynamic separation of foundation in ISS

Summary:

This test of nonregression implements a mode of use of *Code_Aster* to deal with the nonlinear problem of separation of foundation of a building with taking into account of interaction ground-structure (ISS) in dynamic analysis. The ISS is then modelled by a carpet of springs of ground readjusted starting from the impedance of ground determined by means of the chaining of *Code_Aster* with software MISS3D.

One presents to it like case of application the standard case of a building subjected to a seismic excitation treaty with a flexible representation of the foundation having for consequence the total taking into account of the modes of deformation of the foundation raft associated with characteristics of the type `RIGI_MISS_3D`.

The maximum displacements obtained in edge of foundation by a dynamic calculation with `DYNA_NON_LINE` constitute a first result of reference.

In the second modeling, one deals with the same problem by using a method of condensation dynamic of the building which is then represented by a macro - dynamic component of under - structuring. The ground is represented directly by an impedance of ground determined by means of the chaining of *Code_Aster* with software MISS3D and considered also as a macro - dynamic component. The resolution of the dynamic problem with `DYNA_NON_LINE` take place on a mixed model made up of the macro - elements and a physical model reduced to the nonlinear springs of contact. This method more exact and more economic than the preceding one provides however values close enough for maximum displacements obtained in edge to foundation.

In the third modeling, one uses the same method of condensation as in the second modeling but the resolution of the dynamic problem takes place in a loop of linear calculations with the operators of transitory dynamics where one each time recomputes on all the temporal beach the complement of nodal forces due to nonthe linearity of separation. This method is even more economic than the preceding one and provides satisfactory values for maximum displacements obtained in edge of foundation.

1 Problem of reference

1.1 Geometry

Software *Code_Aster*- MISS3D uses the frequential method of coupling to take account of the interaction ground - structure. This method, based on under - dynamic structuring, consists in cutting out the field of study in three pennies - fields:

- ground,
- the foundation,
- the building.

The geometry taken into account is that of a hollow cylindrical building on its circular foundation.

Geometry of the building unit - foundation

The geometry is represented on [Figure 1.1-a] below:

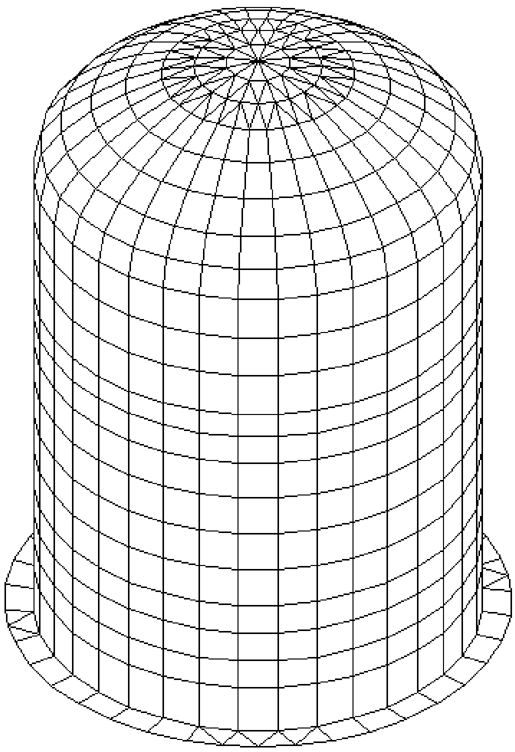

Figure 1.1-a: Geometry of the building unit - foundation

1.2 Properties of materials

One considers an average homogeneous ground of type MC of which the characteristics (respectively Young modulus E, Poisson's ratio ν, density ρ and damping hysteretic β) are summarized in the table hereafter:

Sleep	Thickness (m)	ρ (kg/m^3)	ν	E (MPa)	$\beta=2\,\mathrm{h}$ (hyst.)
Lay down 1	25	2100	0.4	2800	0.1

Table 1.2-1: Soil mechanics characteristics homogeneous

The foundation and the building out of concrete reinforced and are respectively prestressed of which the characteristics (Young modulus E, Poisson's ratio ν, density ρ) are summarized in the table hereafter:

Material	E (Pa)	ρ (kg/m^3)	ν
armed	4.0 E10	3000	0.31
prestressed	4.0 E10	2500	0.31

Table 1.2-2: Mechanical characteristics of the concretes

1.3 Boundary conditions and loadings mechanical

The foundation is regarded as flexible without solid connection on the group of meshs of the foundation. The seismic excitation mono-support of the structure is carried out by applying 1 accélérogramme resulting from spectrum UNS-LB in the horizontal direction X:

Direction	Accélérogramme	Normalizes
X	acc1.c2	$0.35\,g$

Table 1.3-1: Seismic excitation

One thus gives here the accélérogramme (normalized to $0.15\,g$).

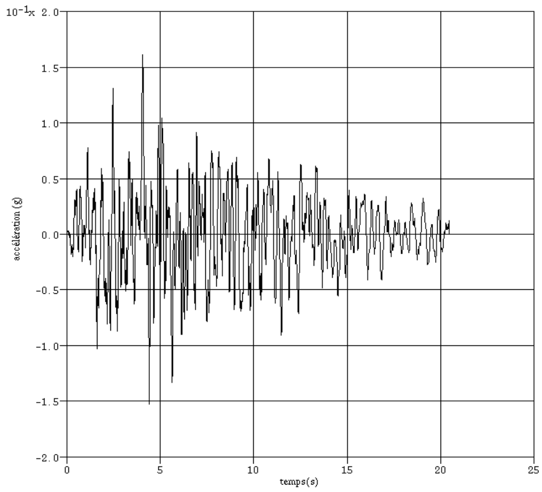

Figure 1.3-a: Accélérogramme acc1.c2

2 Method of calculating on flexible foundation

To represent the flexible assumption of foundation amounts taking into account the limiting condition of calculation of the modes of foundation. One uses the following method for modeling A of the case test.

2.1 Description of the method

The flexible condition of foundation is obtained by representing the static modes of foundation by constrained modes associated with all the degrees of freedom of translation of the foundation.

Consequently, for the calculation of the clean modes on blocked basis, one will then block all the degrees of freedom of translation ($DX = DY = DZ = 0$) group of nodes $BRADIER$ [Figure 3.1-a] of the foundation in the order AFFE_CHAR_MECA [U4.44.01]. For the calculation of the static modes of foundation, one will obtain the constrained modes associated with each degree of freedom blocked in these nodes. The number of static modes to calculate rises then with the number of nodes on the foundation multiplied by 3, the number of associated degrees of freedom of translation.

Then, once obtained the calculation of the impedances depending on the frequency by the option FILE order CALC_MISS, one can then affect readjusted total characteristics of the foundation by means of the operator AFFE_CARA_ELEM [U4.42.01] option RIGI_MISS_3D.

2.2 Synthesis of the calculation of the impedances

The calculation of the impedances of ground requires to place by the following stages of sequence of the orders of *Code_Aster* :

- Calculation of the clean modes on basis blocked with limiting conditions of blocking compatible with the assumption of foundation by the order CALC_MODES [U4.52.02],
- Definition of the dynamic interface, producing the type (CRAIGB (recommended) or MCNEAL) and grid of the interface ground - structure, by the order DEFI_INTERF_DYNA [U4.64.01],
- Definition of a modal base supplements by the order DEFI_BASE_MODALE [U4.64.02] which calculates the static modes of the dynamic interface previously definite and supplements the base of the clean modes with the complete modal base of type CLASSIC,
- Assembly of the macro - dynamic component by the order MACR_ELEM_DYNA [U4.65.01], starting from the modal base previously definite.
  Data to be transferred from *Code_Aster* towards MISS3D are obtained by the use of a specific order:
- The order IMPR_MACR_ELEM [U7.04.33] allows to produce the grid of the interface ground-structure and the modes static and dynamic reduced to this interface. The terms of the macro - dynamic component are used to establish the contribution of the structure on the impedance.
- Then one obtains the calculation of the impedances of ground by the launching of MISS3D by CALC_MISS [U7.03.12] option FILE. In data of this order, in addition to the file produced by IMPR_MACR_ELEM, it is necessary to provide a file of parameter setting of calculation as well as a data file of ground as described in the document **[bib3]**.

3 Modeling of separation with springs of ground

The simultaneous modeling of separation and the ISS by discrete elements then requires to combine the use of linear springs representing the ground and nonlinear springs working only in compression to represent the contact by penalization. An example of modeling adapted to the modeling of a building under seismic request is described Ci - afterwards.

3.1 Coupling between springs of ground and springs of contact

In the case of a building subjected to a seismic excitation which one wants to study the interaction ground-structure (ISS), the base of the foundation must be represented geometrically by surface meshs, grouped here in $SRADIER$, which can not be modelled in flexible assumption of foundation when they are pressed on voluminal elements.

In the case of a linear behavior, one can directly assign to the nodes $SRADIER$ characteristics of rigidity calculated by the option of AFFE_CARA_ELEM, RIGI_MISS_3D, for the flexible assumption of foundation. On the other hand, to represent separation, it is necessary that these characteristics of ground are active only in the event of compression of the ground and that they are cancelled in the event of traction. An average classic consists in intercalating, between each point of the foundation $SRADIER$ and an affected specific spring of the characteristics of ground in this point, a spring in nonlinear series with a grid by a segment supporting a modeling DIS_TR in rigid assumption of foundation or DIS_T in flexible assumption of foundation. This group of discrete segments is called here $LIGRAD$. The characteristics of these springs of contact are very high in compression (10^{15} in this test) and worthless in traction. They are indicated with a behavior material DIS_CONTACT then affected with the law of behavior DIS_CHOC in an operator of calculation of evolution. The characteristics of the series of springs consisted the segment comes out from contact and the specific spring of ground will be thus those of this last in compression (10^{15} in this test) and worthless in traction.

To calculate the characteristics of specific springs of ground grouped here in $BRADIER$, it is necessary that the nodes of this group belong to surface meshs of the same geometry than $SRADIER$. However, $SRADIER$ does not contain any more the nodes of $BRADIER$ because segments of $LIGRAD$ are inserted. It is thus necessary to create in the grid a group of surface meshs called here $SRADIE2$ while relocating $SRADIER$ of a value of very small distance equalizes in keeping with segments of $LIGRAD$ ($2.\mathrm{E}-2$ in this test). This value of distance is found then like game in the material characteristics DIS_CONTACT so that the ground and the foundation are jointed in the initial time. The group of surface meshs $SRADIE2$ need does not have to be modelled by finite elements.

The whole of modelings of springs of ground and contact is schematized thus [Figure 3.1-a]:

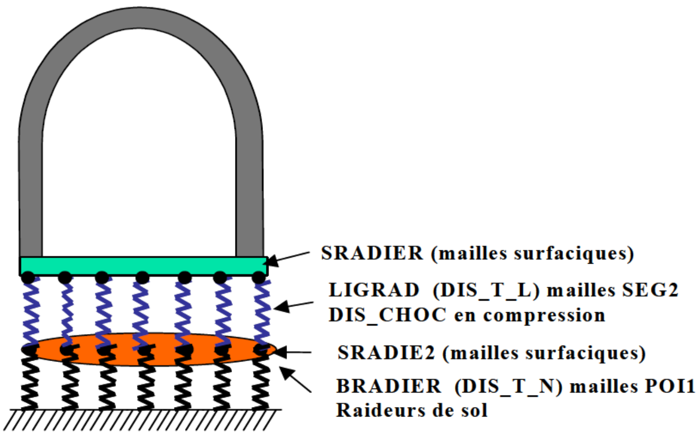

Figure 3.1-a: Model of interface ground – structure coupling springs of contact and springs of ground

3.2 Calculation of the modes on carpet of springs of ground

The calculation of the modes on carpet of springs of ground is desirable. It is even necessary if one wants to take into account thereafter modal depreciation during dynamic calculation.
As a preliminary, it is necessary to calculate the characteristics of ground with the option of AFFE_CARA_ELEM, RIGI_MISS_3D, for the flexible assumption of foundation. These are the new characteristics which will be affected instead of the preceding ones and associated with the limiting condition of blocking at the same time for the calculation of the modes on carpet of springs of ground but also in the operators of calculation of evolution.
For RIGI_MISS_3D, one enters the group of specific meshs $BRADIER$ under GROUP_MA_POI1. It is enough to inform the logical number of unit of the matrix of impedance of ground calculated by MISS3D that one already gave in CALC_MISS option MISS_IMPE.

3.3 Dynamic calculation of separation

Before calculating the dynamic evolution of separation, it is necessary to calculate the static depression due to gravity. One thus passes by the following stages of modeling:

- Definition of the load of vertical gravity and the horizontal unit loads of type "gravity" for the seismic loading,
- Definition of the list of the moments of dynamic calculation,
- Calculation of the static position under the effect of gravity by the order STAT_NON_LINE [U4.51.03]: discrete segments $LIGRAD$ are affected by the relation of behavior DIS_CHOC. The rest of the structure has a linear behavior in our case but the interest of this modeling is also to be able to affect other relations of behavior,
- Calculation of the dynamic evolution, with recovery like initial state of the preceding static result, under the effect of gravity always and also of the seismic loads by the order DYNA_NON_LINE [U4.53.01]. Discrete segments $LIGRAD$ are also affected by the relation of behavior DIS_CHOC. It is on this level that one can introduce modal depreciation associated with each mode on carpet of springs of ground calculated previously.

4 Modeling of separation by dynamic condensation

The one second active alternative modeling for modelings B and C of the case test consists in dealing with the same problem by using a method of dynamic condensation of the building which is then represented by a macro - dynamic component of under-structuring. One condenses there the building by his modes of interface with the foundation and the nonlinear springs of contact. The ground is represented directly by the preceding impedance of ground considered also as a macro - dynamic component instead of the assignment of springs of ground by AFFE_CARA_ELEM, and option RIGI_MISS_3D or RIGI_PARASOL. One finds the preceding stages with the difference close that the resolution of the dynamic problem with DYNA_NON_LINE take place on a mixed model made up of the macro - elements and a physical model reduced to the nonlinear springs of contact $LIGRAD$ affected by the relation of behavior DIS_CHOC. Moreover, to recover the fields on the structure, it is necessary to make a restitution on physical basis by REST_COND_TRAN starting from its macro - element.

5 Reference solution

5.1 Method of calculating used for the reference solution

Case test of nonregression

5.2 Results of reference

One retains like results of reference the initial depression under the effect of the weight as well as the maximum relative ones of separation corresponding to the vertical displacements noted during dynamic calculation at the 2 ends according to the direction X foundation.

One also retains like result of reference horizontal displacement obtained to the top of the building at the final moment.

5.3 Bibliographical references

1 V. GUYONVARH - G. DEVESA - NR. GREFFET - D. CLOUTEAU: The interaction ground-structure in Nuclear industry. Note EDF R & D HT-62/03/028/A

2 D. CLOUTEAU: User's manual of PROMISS3D - MISS2D, revision 6.3, by (LMSSM Central School of Paris).

3 G. DEVESA - V. GUYONVARH: Interaction ground-structure in seismic analysis with the interface *Code_Aster* - PROMISS3D. Document Aster U2.06.07-A.

6 Modeling A

6.1 Characteristics of modeling

6.1.1 Grid of the foundation

The foundation circular and is modelled by 242 elements of hull DKT of thickness $6{,}1\,m$.

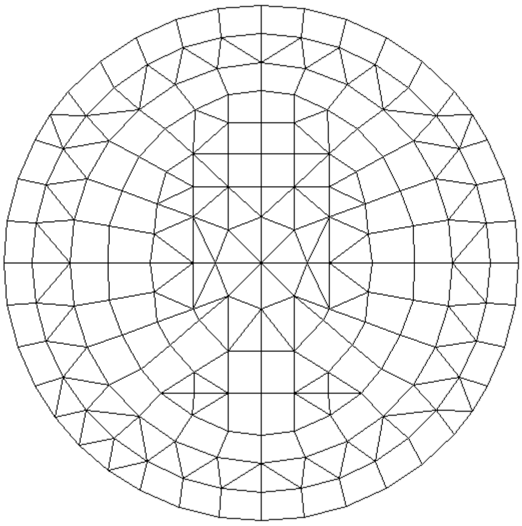

Figure 5.1-a: Grid of the foundation of the building

6.1.2 Grid of the building

The building consists of a surmounted circular barrel of a dome and can be modelled by 756 elements of hull DKT of thickness $1{,}4\,m$.

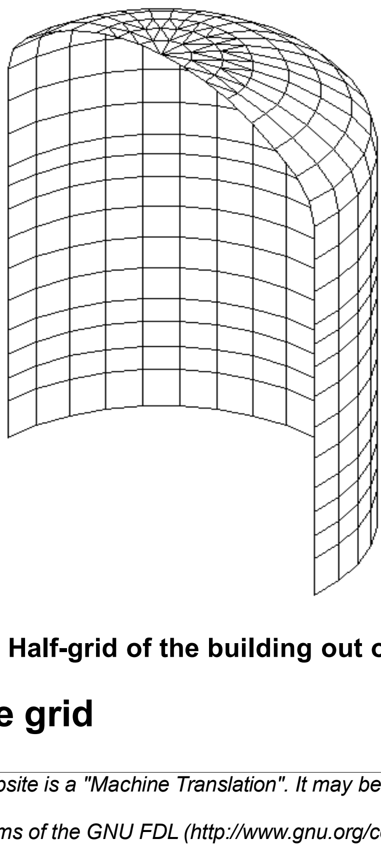

Figure 5.1-b: Half-grid of the building out of vertical cut

6.2 Characteristics of the grid

The model is composed of 1057 nodes (5784 degrees of freedom), 1797 elements (998 discrete elements plates and 799 elements).

6.3 Parameters of calculation

Dynamic calculation is carried out on a 0.4 seconds interval per step of times of 0.01 second with a modal damping, calculated by `CALC_AMOR_MODAL`, different for each mode whose frequency is lower than $20\,Hz$ and including a contribution of material damping of 5% for the structure of building and a contribution representative of radiative damping of the ground extracted the imaginary part of the impedance of ground.

6.4 Results of modeling A

Tests of non- regressions are made on the values of displacements (vertical and horizontal) of the nodes top and center of the foundation raft, at the beginning of the transient and the end.

7 Modeling B

7.1 Characteristics of modeling

This modeling implements the method of condensation dynamic of the structure and the ground. One uses mixed model made up of their macro - elements and a physical model reduced to the nonlinear springs of contact. Modeling is based on the same elements and the same grid as the preceding one unlike springs of ground of $BRADIER$ replaced by the macro - element directly made up of the impedance of ground calculated by MISS3D.

7.2 Characteristics of the grid

The model is composed of 1057 nodes (5784 degrees of freedom), 1184 elements (998 discrete elements plates and 186 elements).

7.3 Parameters of calculation

Dynamic calculation is carried out on a 3 seconds interval per step of 0.01 second time with a damping of 5% for each mode of structure whose frequency is lower than $20\,Hz$ combined with a matrix of damping extracted the macro - element of ground and representative of radiative damping, which is equivalent to the modal damping of preceding modeling.

7.4 Results of modeling B

Tests of not-regressions are made on the values of displacements (vertical and horizontal) of the nodes top and center of the foundation raft, at the beginning of the transient and the end.

8 Modeling C

8.1 Characteristics of modeling

This modeling uses exactly the same mixed model made up by macro - elements and a physical model reduced to the nonlinear springs of contact that in the second modeling. The difference lies only in the method of resolution in a loop of linear calculations with the operators of transitory calculation where one recomputes each time the complement of nodal forces due to nonthe linearity of separation by means of the operator CALC_FORC_NONL. One proceeds here to 6 iterations of linear calculations.

8.2 Characteristics of the grid

The model is composed of 1057 nodes (5784 degrees of freedom), 1184 elements (998 discrete elements plates and 186 elements).

8.3 Parameters of calculation

Dynamic calculation is carried out on a 5 seconds interval per step of time of 0.01 second with a damping of 5% for each mode of structure whose frequency is lower than $20\,Hz$ combined with a matrix of damping extracted the macro - element of ground and representative of radiative damping, which is equivalent to the modal damping of the first modeling.

8.4 Results of modeling C

Tests of not-regressions are made on the values of displacements (vertical and horizontal) of the nodes top and center of the foundation raft, at the beginning of the transient and the end.

9 Summary of the results

The method of representation of the ISS by a carpet of springs of ground used in modeling A provides results of nonregression in term of maximum displacements obtained in edge of foundation to the initial moment and during an separation.

An alternative method of representation of the ISS and structure by dynamic condensation are used in modeling B. This more exact method (because using all the terms of the impedance of ground) and more economic (because of dynamic condensation) that the preceding one provides however values close enough for maximum displacements obtained in edge to foundation.

It is thus it which one will use in priority at the time of the dynamic studies of separation.

It is also used in the modeling C in which the resolution of the dynamic problem takes place in a loop of linear calculations with operators of transitory calculation where one each time recomputes on all the temporal beach the complement of nodal forces due to nonthe linearity of separation. This method of resolution is even more economic than the preceding one and provides satisfactory values for maximum displacements obtained in edge of foundation