SDLX106 – Impedances of ground under a rectangular foundation inserted in a homogeneous medium

Summary:

This test takes part with validation of the chaining *Code_Aster* - MISS3D. It represents a standard case of calculation of impedances of ground under a rectangular foundation inserted in a homogeneous medium. The transfer functions opposite transfer of the impedances obtained by the chaining enters *Code_Aster* and MISS3D are compared with those obtained by another method of calculating, using an exclusive modeling by *Code_Aster* , where one represents the condition of infinite medium by elements absorbents assigned to the borders of a homogeneous volume of ground surrounding the foundation. Variations are obtained of approximately 10% per 2 values of frequency chosen respectively in the low range and the high range.

1 Problem of reference

1.1 Geometry

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

- the ground (which is discretized in elements of borders),
- the foundation (which is with a grid in EF),
- the structure (which is with a grid in EF and represents the building and/or a limited field of ground).

Ground

The ground corresponds to a layer of semi-infinite homogeneous medium.

The foundation

The rectangular foundation is represented on [Figure 1.1-a] below. It has as dimensions a length of $24\,m$ in the direction X, a width of $12\,m$ in the direction Y and a height of depression of $8\,m$. It is modelled then by 108 surface elements. To accelerate calculations, one voluntarily déraffiné in height: in practice, it would be necessary to use meshs of form square and thus twice more meshs in height.

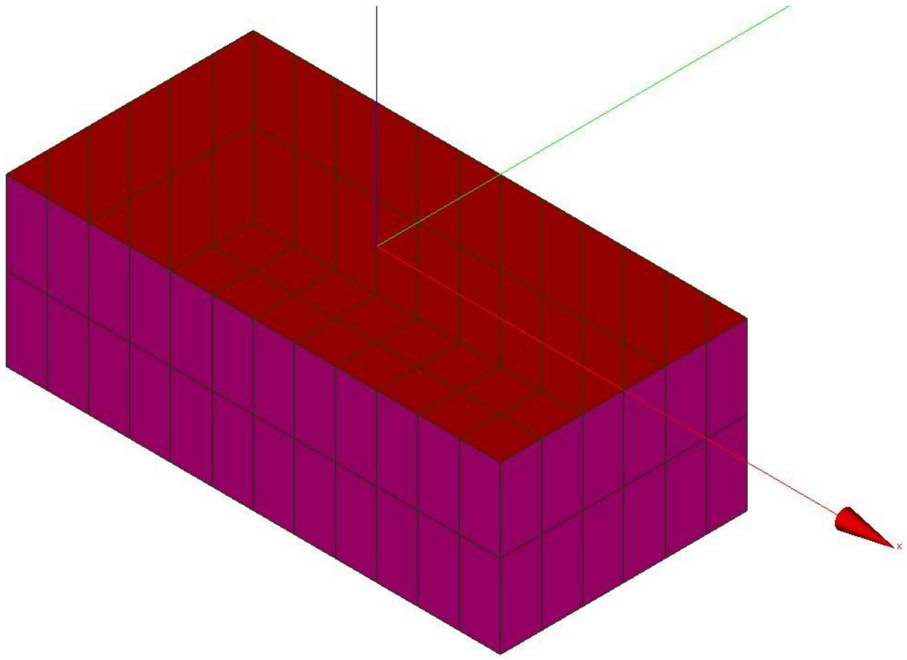

Figure 1.1-a: Surface grid of the foundation

The structure

The structure consists of solid elements representing a homogeneous volume of ground surrounding the foundation. It has as dimensions a length of $72\,m$ in the direction X, a width of $72\,m$ in the direction Y and a height of depression of $36\,m$. It is modelled then by 11520 solid elements. The structure is represented on [Figure 1.1-b] below.

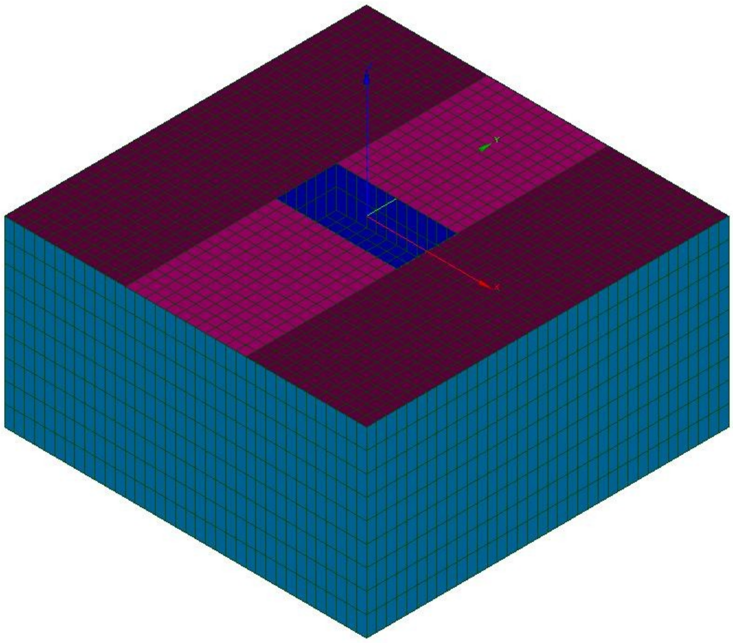

Figure 1.1-b: Voluminal grid of the structure

Ground

The mechanical characteristics of the elastic model of ground which were used are those indicated below. They make it possible to obtain a speed of wave of shearing of $800\,m/s$ for the homogeneous ground.

E (N/m^2)	4.13 E9
ν	0,333
ρ (kg/m^3)	2420
AMOR_HYST	0.1

The foundation and the structure

The mechanical characteristics of the foundation and the structure which were used are the same ones as those of the ground described above.

1.2 Boundary conditions and loadings mechanical

To calculate the 6 static modes of rigid body of the foundation and the clean modes, one blocks the 6 degrees of freedom of translation and rotation of the central node at the base of the foundation by imposing a solid relation of connection there. One also applies in this central node 6 loadings of nodal force of module 1.E6 of each of the 6 components of translation and rotation.
One then obtains like answers to these 6 requests transfer functions opposite the transfer of the impedances by two ways of harmonic calculation: that is to say a modal calculation on the basis of static mode of foundation by directly reversing the impedances obtained by the chaining enters *Code_Aster* and MISS3D on a scale model with the foundation, is a calculation on physical basis by another method using an exclusive modeling by *Code_Aster* of a great volume of homogeneous ground surrounding the foundation: with this modeling, one represents the condition of infinite medium by surface elements absorbents assigned to the borders of this volume.

2 Reference solution

2.1 Method of calculating used for the reference solution

The results of reference are the impedances of ground obtained starting from the fields of incidental displacements and the induced constraints calculated by software MISS3D in various levels of depth of a laminated ground. The incidental field on the surface of the ground is considered unit in each direction of the space and for any frequency of request. Variation of this field in the depth of the ground, or déconvolution, is obtained starting from functions of Green. These functions constitute a base of elementary solutions, representing the answer, in various receiving levels, with unit requests in various levels sources of the ground [bib1].

2.2 Results of reference

One compares transfer functions opposite the transfer of the impedances obtained by the chaining enters *Code_Aster* and MISS3D with those obtained by the other method of calculating, using an exclusive modeling by *Code_Aster*, where one represents the condition of infinite medium by elements absorbents assigned to the borders of a great volume of homogeneous ground surrounding the foundation.
One will be able to also compare the values of impedance for each of the 6 directions of rigid body obtained by inversion of the preceding transfer transfer functions to those given by the reference [bib2] making the synthesis of several digital or semi-analytical studies carried out by various authors.

2.3 Bibliographical references

1 D. CLOUTEAU: “Manual of reference of MISS3D – version 6.3 – Power station Searches SA”

2 J.G. SIEFFERT & F. CEVAER: “Calculation of the impedances of foundation – Nantes Power station – Ouest-France Editions”

3 Modeling A

3.1 Characteristics of modeling

The characteristics used and the grid are those deduced from the data of [§1]. One uses 2 frequencies of calculation corresponding respectively to a frequency of the low range and one frequency of the high range for respective values of adimensional parameter of frequency $a0=\omega R/Vs$ of 0.4 and 1.2 that is to say 8.5 and $25.5\,Hz$ if one takes a value of $6\,m$ for R equalize with the half-width of the foundation.
One use in `CALC_MISS` automated way of calculating of the parameters of MISS3D.

3.2 Characteristics of the grid

Grid provided to *Code_Aster* contains meshs of the types QUAD4 to model the rectangular foundation modelled by elements `DST`. It is important to have directed the elements of surface of the foundation with normal returning in the ground. One obtains in all 108 surface meshs for the foundation with a size of mesh of $2\,m$ approximately into horizontal and $4\,m$ into vertical (one déraffiné into vertical to decrease the computing time but the value recommended is of $2\,m$).

The grid also contains 23040 meshs of the type HEXA8 to model the homogeneous volume of ground surrounding the foundation with solid elements 3D. Surface external of this volume of ground is discretized by 3888 meshs QUAD4 affected by elements `3D_ABSO` to represent the condition of absorbing border.

3.3 Sizes tested and results

The transfer functions opposite transfer of the impedances obtained by the chaining enters *Code_Aster* and MISS3D are compared with those obtained by another method of calculating, using an exclusive modeling by *Code_Aster*, where one represents the condition of infinite medium by elements absorbents assigned to the borders of the homogeneous volume of ground surrounding the foundation.

The values of the transfer transfer functions below are tested for each of the 6 components with 2 values of frequency corresponding respectively to a high range and a low range and to values of $a0$ close relations respectively of 0.4 and 1.2 .

Calculation of reference (Code_Aster only):

Identification	Value of reference	Type of reference	Tolerance
$U11$ ($8.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U11$ ($25.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U22$ ($8.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U22$ ($25.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U33$ ($8.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U33$ ($25.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U44$ ($8.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U44$ ($25.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U55$ ($8.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U55$ ($25.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U66$ ($8.5\,Hz$)	-	`'NRON_REGRESSION'`	-
$U66$ ($25.5\,Hz$)	-	`'NRON_REGRESSION'`	-

Calculation *Code_Aster*- MISS3D:

Comparison with calculation *Code_Aster* only

Identification	Value of reference	Type of reference	Tolerance
$U11b$ ($8.5\,Hz$)	4.405562E-06-3.103320E-06j	'AUTRE_ASTER'	7%
$U11b$ ($25.5\,Hz$)	9.786317E-07-2.972870E-06j	'AUTRE_ASTER'	11%
$U22b$ ($8.5\,Hz$)	4.174931E-06-2.920876E-06j	'AUTRE_ASTER'	9%
$U22b$ ($25.5\,Hz$)	1.042063E-06-2.641335E-06j	'AUTRE_ASTER'	18%
$U33b$ ($8.5\,Hz$)	3.670733E-06-3.539087E-06j	'AUTRE_ASTER'	21%
$U33b$ ($25.5\,Hz$)	5.687622E-07-2.420604E-06j	'AUTRE_ASTER'	18%
$U44b$ ($8.5\,Hz$)	6.997733E-08-1.411643E-08j	'AUTRE_ASTER'	35%
$U44b$ ($25.5\,Hz$)	4.736895E-08-4.387128E-08j	'AUTRE_ASTER'	35%
$U55b$ ($8.5\,Hz$)	3.938570E-08-1.105361E-08j	'AUTRE_ASTER'	26%
$U55b$ ($25.5\,Hz$)	1.757004E-08-2.782686E-08j	'AUTRE_ASTER'	21%
$U66b$ ($8.5\,Hz$)	3.058106E-08-6.790613E-09j	'AUTRE_ASTER'	7%
$U66b$ ($25.5\,Hz$)	1.627885E-08-2.253177E-08j	'AUTRE_ASTER'	11%

Comparison with the bibliographical reference

Identification	Value of reference	Type of reference	Tolerance
$U11b$ ($25.5\,Hz$)	1.2679e-06-3.03637e-06j	'SOURCE_EXTERNE'	0.7%
$U22b$ ($8.5\,Hz$)	4.37312e-06-3.25212e-06j	'SOURCE_EXTERNE'	2%
$U22b$ ($25.5\,Hz$)	1.42056e-06-2.83346e-06j	'SOURCE_EXTERNE'	2%
$U33b$ ($8.5\,Hz$)	4.3762e-06-4.24318e-06j	'SOURCE_EXTERNE'	2%
$U33b$ ($25.5\,Hz$)	6.76519e-07-2.78195e-06j	'SOURCE_EXTERNE'	2%
$U44b$ ($8.5\,Hz$)	8.69847e-08-2.13947e-08j	'SOURCE_EXTERNE'	7%
$U44b$ ($25.5\,Hz$)	6.02497e-08-5.34563e-08j	'SOURCE_EXTERNE'	7%
$U55b$ ($8.5\,Hz$)	4.75128e-08-1.46293e-08j	'SOURCE_EXTERNE'	4%
$U55b$ ($25.5\,Hz$)	2.08904e-08-3.20829e-08j	'SOURCE_EXTERNE'	4%
$U66b$ ($8.5\,Hz$)	3.23981e-08-7.32988e-09j	'SOURCE_EXTERNE'	0.8%
$U66b$ ($25.5\,Hz$)	1.91983e-08-2.22916e-08j	'SOURCE_EXTERNE'	0.8%

4 Summary of the results

The comparison enters transfer functions opposite the transfer of the impedances obtained by the chaining enters *Code_Aster* and MISS3D and those obtained by a calculation on the basis of physical model, exclusively by *Code_Aster*, homogeneous volume of ground surrounding the foundation, gives variations rather important from 18 % on average and going up up to 35 %. That is explained by the following points in Code_Aster calculation alone:

- one independence in frequency in the formulation of the elements absorbents assigned to the borders of volume representing the condition of infinite medium.
- a volume of sufficiently large ground modelled not
- a grid of the ground not sufficiently fine

On the other hand the comparison between calculation by chaining and the results of the bibliographical reference are good. The variations are on average around 2 % with the low value to 0.7 % and the highest value to 7 %.