SDLS118 - Response of a rigid circular foundation with a variable seismic excitation in Summarized

space:

This case test makes it possible to validate the computation of the response of a rigid shallow foundation subjected to a variable seismic motion in space via the macro DYNA_ISS_VARI. The transfer transfer functions of reference come of results obtained by Became moth-eaten and Luco [bib2].

1 Problem of reference

1.1 Geometry

software MISS3D uses the frequential method of coupling to take account of the interaction soil - structure. This method, based on the dynamic substructuring, consists in cutting out the field of study in three subdomains which are the soil, the foundation and the structure. Here the case of a shallow foundation alone is treated (without structure). It is about a circular foundation of radius $R=20\mathrm{m}$. The geometry that of the foundation is treated in the reference [bib1] and represented to paragraph 3.

1.2 Properties of the material

the soil corresponds to a semi-infinite homogeneous medium whose characteristics are summarized in the table hereafter:

Thickness	**Lay down** (m)	$\rho(kg/m^3)$	ν	$E(MPa)$	β
1 40	. 1875	0.33	1800	lay down	0.10
Layer 2	Substratum	1875	0.33	1800	0.10

Table 1.2-1: Soil mechanics characteristics homogeneous

the foundation is considered rigid and without weight.

1.3 Boundary conditions and loadings

the seismic loading consists of a unit excitation in the field of the frequencies. This makes it possible directly to determine the transfer transfer functions (between the seismic excitation and the structural response). The foundation is regarded as rigid. This results in a solid connection of `the GROUP_NO` basemat.

2 Reference solution

2.1 Method of calculating

One uses the function of coherence suggested by Luco and Wong (1986) [bib1]:

$$\gamma(d)=\exp\left[-(\alpha f\, d/c_{app})^2\right]$$

where d the distance between two points indicates i and j on the foundation, f is the frequency and c_{app} the apparent velocity of propagation on the surface of the wave SH. The parameter α can vary from 0.1 with 0.5 according to the case but is generally taken equal to 0.5.

2.2 Quantities and results of reference

Coefficients of covariance obtained by Became moth-eaten and Luco for $\alpha=0.5$ [bib2]:

a_0	A_{11}^{11}	A_{33}^{33}
1.0	0.732	0.730
2.0	0.402	0.416
3.0	0.251	0.270

a0 indicate the nondimensional frequency $a_0=\frac{\omega R}{c}$

For $\alpha=0.0$, one obtains the case without spatial variability, For this case one knows the solution (analytical). The foundation being rigid without weight, the response with a unit excitation is equal to 1.0, independently of the frequency of computation.

2.3 Uncertainties on the solution

No uncertainties.

2.4 Bibliographical references

[bib1] Luco J.E and Wong H.L.: *Response of has rigid foundation to has spatially random ground motion* . Earthquake Engrg. Struct. Dyn. 14,1986, pp.891-908.

[bib2] Luco J.E and Mita A.: *Response of has circular foundation to spatially random ground motion*. J. Engrg.Mech. 113,1987, pp.1-15.

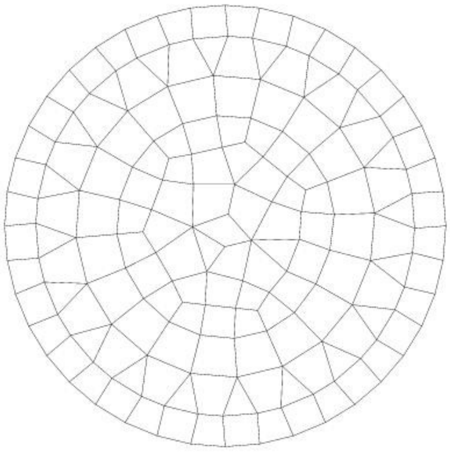
3 Modelization A

3.1 Characteristic of the modelization

the characteristics used and the mesh are those deduced from the data of paragraph 1. One calculated the harmonic response and the transfer transfer functions for the reduced frequencies $a_0 = 1,2,3$ (where $a_0 = \frac{\omega R}{c}$). The results got by Became moth-eaten and Luco for these reduced frequencies are presented in the reference [bib2].

3.2 Characteristics of the mesh

The mesh of the circular foundation is represented below (see §1.1):



3.3 Quantities tested and results

For the case with spatial variability, one chooses $\alpha = 0.5$ and one tests compared to the results of literature (SOURCE_EXTERNE) with a tolerance of 10% .

Results got with DYNA_ISS_VARI for $\alpha = 0.5$ and $c_{app} = 600 \mathrm{m}/s$:

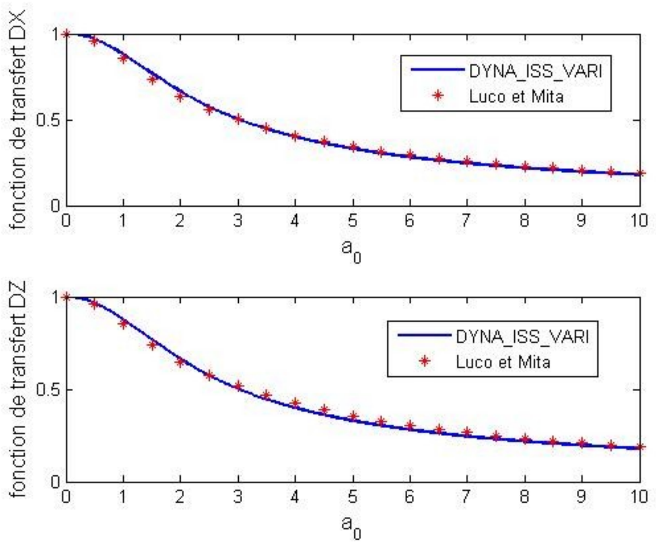
a_0	A_{11}^{11}	A_{33}^{33}
1.0	0.767	0.767
2.0	0.437	0.437
3.0	0.251	0.251

For recall, results of reference [bib2], to also see §2.2:

a_0	A_{11}^{11}	A_{33}^{33}
1.0	0.732	0.730
2.0	0.402	0.416
3.0	0.251	0.270

One in addition make a test of `NON_REGESSION` for the computed values by `DYNA_ISS_VARI` with a tolerance of $0{,}1\%$ (value by default).

Comparison between the transfer transfer functions $\sqrt{A_{ii}^{jj}}$ obtained and `DYNA_ISS_VARI` and with Became moth-eaten and Luco:



For the case $\alpha=0.0$, one tests the response after projection on physical coordinates. The rigid and massless foundation being, all the nodes undergo the same displacement which is equal to 1.0 in direction x for an excitation in direction x.

$$K_S X = K_S X_0$$

K_S is the matrix of modal impedance, X the modal response and $X_0=(1.,0.,0.,0.,0.,0.)$ for a seismic excitation in direction x and $X_0=(0.,0.,1.,0.,0.,0.)$ a vertical seisme.

a_0	A_{11}^{11}	A_{33}^{33}
1.0, 2.0, 3.0	1.0.1.0	

With a projection *via* `REST_SPEC_PHYS`, one obtains result:

a_0	`SPEC N11 "DX"`	`SPEC N11 "DZ"`
1.0	1.00527E+00	1.03014E+00

One carries out a test of the type `ANALYTIQUE` with a tolerance of 1% for "`DX`" and 10% "`DZ`".

4 Modelization B

4.1 Characteristic of the modelization

the characteristics used and the mesh are those deduced from the data of paragraph 1. The mesh is the same one as for modelization A.

One calculated the temporal response with the point $N11$ and determines the corresponding response sprectrum The transfer transfer function being equal to 1 for the case without spatial variability, the temporal response is equal to the entry signal.

If one takes account of spatial variability, then the response is modified.

4.2 Characteristics of the mesh

the characteristics are those of modelization A.

4.3 Grandeurs tested and Function

4.3.1 results of coherence of Mita&Luco

It is checked that, for $\alpha=0.0$, the response in acceleration is equal to the accelerogram as starter of computation (it is pointed out that the transfer transfer function is worth 1 and that the function is rigid for this case of study). One determines the response $q(t)$ in "DX" with the point $N11$ for an excitation $a(t)$ in "DX". One calculates the error like the standard deviation of the difference (residue) between the signal and the response. This is done for the case where the transfer transfer function is calculated for all the points (discretization of the accelerogram) and for the case where the user informs FREQ_PAS, FREQ_FIN. In this last case, DYNA_ISS_VARI interpolates computed values to determine the temporal response due to the excitation by the accelerogram.

type of test	value of reference	tolerance (ab.)
ANALYTIQUE	0.0	0.01

In the same way, for $\alpha=0.0$, the oscillating response sprectrum (SRO) of the response in calculated acceleration must be equal to the SRO of the accelerogram in entry. Thus, one tests the error, namely the difference between these two SRO. One compares evaluates in particular the maximum difference between the two SRO and the standard deviation of the typical mistake

of test	value	value of reference	tolerance (ab.)
ANALYTIQUE	MAX	0.0	0.01
ANALYTIQUE	STANDARD DEVIATION	0.0	0.001

For the case with spatial variability, the values $\alpha=0.7, V_s=200\mathrm{m}/s$ was selected. One considers a temporal seismic excitation in direction "DX" given by an accelerogram corresponding to spectrum EUR for a rock site (cf, curves red figure below). There is no reference solution (analytical) for this case. Also, one makes a test of NON_REGRESSION for the SRO obtained with spatial variability. Two cases are tested.

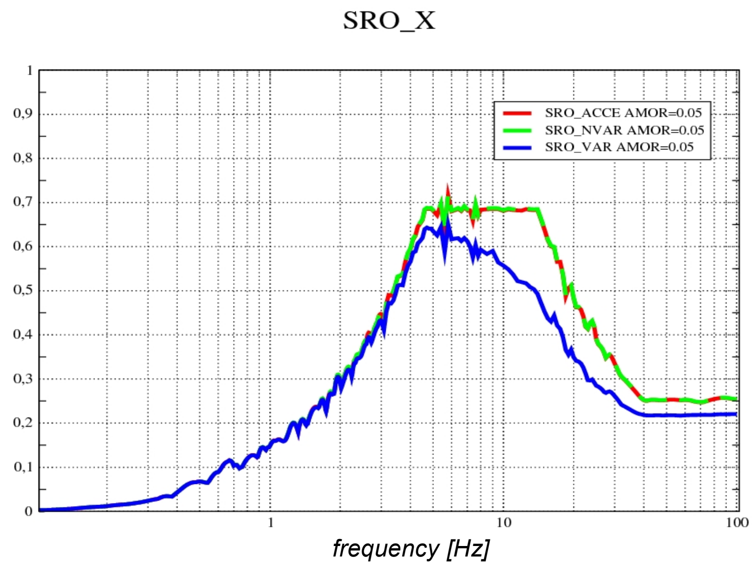
1) `FREQ_FIN` is equal to the cut-off frequency:

type of test	frequency (Hz)	reference SRO (G)	tolerance (%)
NON_REGRESSION	10.0	5.34727E-01	2*10-4
NON_REGRESSION	30.0	2.3855E-01	2*10-3

2) `FREQ_FIN` is lower than the cut-off frequency (35Hz instead of 50Hz) and one supplements by zero:

type of test	frequency (Hz)	reference SRO (G)	tolerance (%)
NON_REGRESSION	10.0	5.34727E-01	
2*10-1	NON_REGRESSION	30.0	2.3855E-01

2*10-2 the response sprectrum of accelerogram (`SRO_ACCE`) and calculated in response with the point $N11$, without spatial variability (`SRO_NVAR`) and with spatial variability (`SRO_VAR`), are shown on the figure below:



Note: For the case test, time step of the Euro accelerogram was multiplied by 2 (0.013672s instead of 0.006836s) in order to accelerate computations. Also, the SRO calculated in sdls118b, go from 0 *to* 50Hz *and not from* 0 *to* 100Hz *as on the figure above.*

4.3.2 Function of coherence of Abrahamson

One considers a temporal seismic excitation in direction "`DX`" given by an accelerogram corresponding to spectrum EUR for a rock site (cf, curves red figure above). One makes a test of `NON_REGRESSION` for the SRO obtained with spatial variability:

type of test	frequency (Hz)	reference SRO (g)	tolerance (%)

NON_REGRESSION	10.0	5.7225E-01	2*10-4
NON_REGRESSION	30.0	2.3903E-01	2*10-3

5 Modelization C

5.1 Characteristic of the modelization

the characteristics used and the mesh are those deduced from the data of paragraph 1. One calculated the harmonic response and the transfer transfer functions for the reduced frequencies $a_0=1,2,3$ (where $a_0=\frac{\omega R}{c}$). The results got by Became moth-eaten and Luco for these reduced frequencies are presented in the reference [bib2].
This modelization is used to test the option of interface of the type " `QUELCONQUE`" of key word `MODE_INTERF` with unspecified modes of foundation different from the modes of rigid body. One will compare his results with those of modelization A.

5.2 Caractéristiques of the mesh

the characteristics are those of modelization A.

5.3 Conditions aux limites of the modelization

For the representation of the motion of foundation, instead of the modes of rigid body of translation, one uses a base of 30 unspecified modes obtained like eigen modes, without conditions of blocking, on carpet of springs established starting from the static impedances of soil for the soil defined in §1,2.
One thus takes as values of total stiffness to distribute under the foundation with option `RIGI_PARASOL` of `AFFE_CARA_ELEM` :
$KX=KY=6.36\text{E}10 \quad KZ=8.02\text{E}10 \quad KRX=KRY=2.07\text{E}13$, $KRZ=2.70\text{E}13$

5.4 Quantities tested and results

For the case $\alpha=0.0$, one tests obligatorily the response after projection on physical coordinates because, unlike the modelization A, the modal coordinates do not coincide with the physical coordinates. The rigid and massless foundation being, all the nodes undergo the same displacement which is equal to 1.0 in direction x for an excitation in direction x . In the same way, all the nodes undergo the same displacement which is equal to 1.0 in direction z for an excitation in direction z .

With a projection *via* `REST_SPEC_PHYS`, one obtains result:

a_0	`SPEC N11 "DX"`	`SPEC N11 "DZ"`
1.0	1.00001E+00	1.00383E+00

One carries out a test of the type `ANALYTIQUE` with a tolerance of 1% for "`DX`" and 10% for "`DZ`".

For the case with spatial variability, one chooses $\alpha=0.5$ and one tests compared to the results of literature (`SOURCE_EXTERNE`) with a tolerance of 10% .
Results got with `DYNA_ISS_VARI` with a projection *via* `REST_SPEC_PHYS`, for $\alpha=0.5$ and $c_{app}=600\text{m}/s$:

a_0	A_{11}^{11}	A_{33}^{33}
1.0	0.767	0.770
2.0	0.437	0.438
3.0	0.251	0.252

For recall, the results of reference [bib2], to also see §2.2:

a_0	A_{11}^{11}	A_{33}^{33}
1.0	0.732	0.730
2.0	0.402	0.416
3.0	0.251	0.270

One in addition makes a test of NON_REGRESSION for the computed values by DYNA_ISS_VARI with a tolerance of $0{,}1\%$ (default value).
One also makes a test AUTRE_ASTER compared to the results of modelization A.

6 Modélisation D

6.1 Characteristic of the modelization

the characteristics used and the mesh are those deduced from the data of paragraph 1. The mesh is the same one as for modelization A.
As for the modelization B, one calculated the temporal response with the point $N11$ and determines the corresponding response sprectrum The transfer transfer function being equal to 1 for the case without spatial variability, the temporal response is equal to the entry signal.
If one takes account of spatial variability, then the response is modified.
This modelization is used to test the option of interface of the type "QUELCONQUE" of key word MODE_INTERF with unspecified modes of foundation different from the modes of rigid body. One will B compare his results with those of the modelization.

6.2 Characteristic of the mesh

the characteristics are those of modelization A.

6.3 Conditions aux limites of the modelization

For the representation of the motion of foundation, instead of the modes of rigid body of translation, one uses a base of 30 unspecified modes obtained like eigen modes, without conditions of blocking, on carpet of springs established starting from the static impedances of soil for the soil defined in §1,2.
One thus takes as values of total stiffness to distribute under the foundation with option RIGI_PARASOL of AFFE_CARA_ELEM :
$KX = KY = 6.36\text{E}10$ $KZ = 8.02\text{E}10$ $KRX = KRY = 2.07\text{E}13$, $KRZ = 2.70\text{E}13$

6.4 Quantities tested and Function

6.4.1 results of coherence of Mita&Luco

It is checked that, for $\alpha = 0.0$, the response in acceleration is equal to the accelerogram as starter of computation (it is pointed out that the transfer transfer function is worth 1 and that the function is rigid for this case of study). One determines the response $q(t)$ in "DX" at the point $N11$ for an excitation $a(t)$ in "DX". One treats the case where the transfer transfer function is calculated for all the points (discretization of the accelerogram) and the case where the user informs FREQ_PAS, FREQ_FIN. In this last case, DYNA_ISS_VARI interpolates computed values to determine the temporal response due to the excitation by the accelerogram.
One checks as into 4,3,1 that the oscillating response sprectrum (SRO) of the response in calculated acceleration is equal to the SRO of the accelerogram as starter.

type of test	frequency (Hz)	reference SRO (g)	tolerance (%)
ANALYTIQUE	10.0	0.6573	0.1
ANALYTIQUE	30.0	0.2970	0.2

For the case with spatial variability, the values $\alpha = 0.7, V_s = 200\text{m}/s$ were selected. One considers a temporal seismic excitation in direction "DX" given by an accelerogram corresponding to spectrum EUR for a rock site (cf, curves red figure in §4.3.1). There is no reference solution (analytical) for this case. Also, one makes a test of NON_REGRESSION for the SRO obtained with spatial variability.
One also makes a test AUTRE_ASTER compared to the results of the modelization B.
One tests two cases.

1) FREQ_FIN is equal to the cut-off frequency:

type of test	frequency (Hz)	reference SRO (G)	tolerance (%)
NON_REGRESSION	10.0	0.5418	0.0001
NON_REGRESSION	30.0	0.2348	0.0002
AUTRE_ASTER	10.0	0.535	1.3E0
AUTRE_ASTER	30.0	0.2386	1.6E0

2) FREQ_FIN is lower than the cut-off frequency ($35\mathrm{Hz}$ instead of $50\mathrm{Hz}$) and one supplements by zero:

type of test	frequency (Hz)	reference SRO (G)	tolerance (%)
NON_REGRESSION	10.0	0.5418	0.0002
NON_REGRESSION	30.0	0.2333	0.0001
AUTRE_ASTER	10.0	0.535	1.2E0
AUTRE_ASTER	30.0	0.2386	2.2E0

6.4.2 Function of coherence of Abrahamson

One considers a temporal seismic excitation in direction "DX" given by an accelerogram corresponding to spectrum EUR for a rock site (cf, curves red figure in §4.3.1). One makes a test of NON_REGRESSION for the SRO obtained with spatial variability. One also makes a test AUTRE_ASTER compared to the results of standard modelization

b: of test	frequency (Hz)	reference SRO (G)	tolerance (%)
NON_REGRESSION	10.0	0.5747	0.0001
NON_REGRESSION	30.0	0.23877	0.0001
AUTRE_ASTER	10.0	0.5723	0.4
AUTRE_ASTER	30.0	0.23903	0.1

7 Summary of the results

This case test allows to validate command DYNA_ISS_VARI through the computation of the response of a rigid shallow foundation represented either by modes of rigid body (MODE_INTERF=' CORPS_RIGI'), or by unspecified modes on carpet of springs determined starting from the static impedances of soil (MODE_INTERF=' QUELCONQUE'). The results got with DYNA_ISS_VARI are in concord with the results of the reference of Became moth-eaten and Luco.