SDLL108 - “Array with coffee” of NEUBERT

Summarized

This multidirectional problem consists in carrying out a spectral seismic analysis of a structure made up of beam elements without masses and discrete masses to the nodes. It understands a modelization.

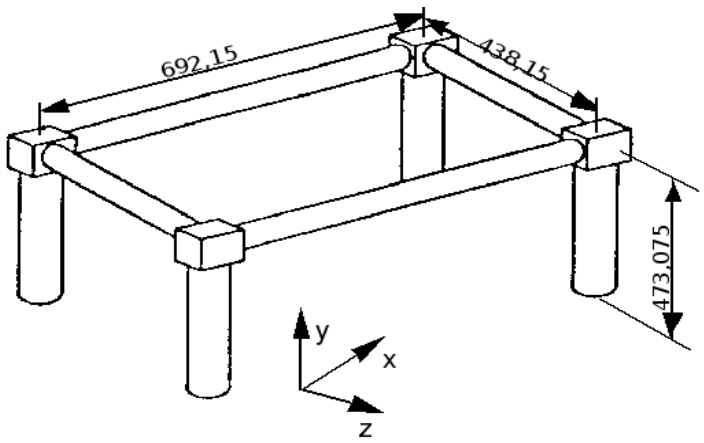
The seismic excitation is provided in the shape of three response sprectrums of oscillators in acceleration to the bearings according to the axes X , Y and Z .

Via this problem, one tests command MODE_STATIQUE and the options of quadratic combination of the modes and quadratic combination and combination of Newmark of the directions of excitations of the command COMB_SISM_MODAL.

The got results are in concord with the results of reference got with the code HERCULES.

1 Problem of reference

1.1 Geometry



$L = 0.69215\, m$
$I = 0.43815\, m$
$H = 0.473075\, m$

hollow circular Section:
$d_e = 0.060\, m$
$d_i = 0.052\, m$
$S = 0.7037\, 10^{-3}\, m^2$
$I_y = I_z = 0.2772\, 10^{-6}\, m^4$
$A_y = A_z = 2.$
$C_y = 0.5545\, 10^{-6}\, m^4$

1.2 Material properties

$E = 1.92276\, E11\, N/m^2$
$\nu = 0.3$
$\rho = 0.\, kg/m^3$

1.3 Boundary conditions and loadings

- clamped Structure at its base,
- Modal dampings of $2\,\%$.

Definition of the spectrum of acceleration to the bearings

Frequency	X Z	Y
100	17.3	11.5
110	16.3	10.9
120	15.3	10.2
130	14.3	9.6.300
	10.2	6.66

- for a damping of $2\,\%$,
- acceleration in g .

2 Reference solution

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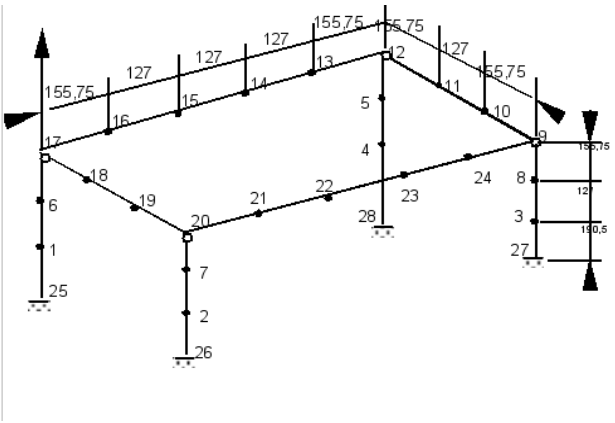
2.1 Method of calculating used for the reference solution

the results of reference were got with the code HERCULES [2]. The model finite elements used is identical has that used for the modelization A carried out with *Code_Aster*.



Net $1019 : N6-N17$
$1009 : N17-N18$
$1008 : N17-N16$

Masses of corners : $4.444\,kg$

Intermediate masses : $0.783\,kg$

The geometrical dimensions used in computations with HERCULES are very slightly different from those presented to the §1.1:

- $L=692.50\,mm$
- $I=438.50\,mm$
- $H=473.25\,mm$

2.2 Results of reference

- Eigenfrequencies
- Displacements to the points constituting the corners of the array,
- Reactions of bearings to the anchorages,
- Internal forces with the “corners”.

Identification	Reference	effective Masses (% of the total mass)		
Mode	Frequency (Hz)	X	Y	Z
1	110.857	94.2	0.0.0.0	
2	115.471	0.0.0.0		94.4
3	135.936	0.0.0.0. 0.0		
4	213.541	0.0.0.0. 0.0		

5	417.332	0.0.0.0. 0.0		
6	434.813	0.0	24.1	0.0
7	464.097	0.0.0.0. 0.0		
8	557.262	0.0.0.0. 0.3		
9	821.746	0.0	18.0	0.0
10	847.071	0.0.0.0. 0.0		
11	978.174	1.6.0.0. 0.0		
12	991.842	0.0.2.2. 0.0		
13	1021.669	1.8.0.0. 0.0		
14	1040.240	0.0.0.0. 0.0		
15	1056.948	0.0.0.0. 0.2		
16	1088.861	0.0	18.8	0.0
17	1093.157	1.2.0.0. 0.0		
18	1107.870	0.0.0.0. 0.0		

Identification			Values obtained with combination: quadratic of the directions of the excitations	Values obtained with combination: of NEWMARK of the directions of the excitations
Displacement:				
$N17$		$DX(m)$	3.4246E-04	3.4265E-04
		$DY(m)$	4.3562E-06	4.8392E-06
		$DZ(m)$	3.0321E-04	3.0324E-04
		$DRX(rad)$	3.7031E-04	3.7612E-04
		$DRY(rad)$	4.7665E-05	5.2602E-05
		$DRZ(rad)$	5.1104E-04	5.2310E-04
Reactions:				
$N25$		$FX(N)$	1.2536E+03	1.2790E+03
		$FY(N)$	1.2473E+03	1.3868E+03
		$FZ(N)$	1.2196E+03	1.2441E+03
		$MX(N.m)$	3.2474E+02	3.2789E+02
		$MY(N.m)$	4.1310E+00	4.5579E+00
		$MZ(N.m)$	3.4846E+02	3.5199E+02
Forces:				
1019	$N17$	$FX(N)$	1.1312E+03	1.1486E+03
		$FY(N)$	1.2431E+03	1.3793E+03
		$FZ(N)$	1.0982E+03	1.1141E+03
		$MX(N.m)$	2.2833E+02	2.2982E+02
		$MY(N.m)$	4.1301E+00	4.5580E+00
		$MZ(N.m)$	2.2068E+02	2.2537E+02
1009	$N17$	$FX(N)$	1.8813E+02	2.0079E+02

		$FY(N)$	1.0419E+03	1.0650E+03
		$FZ(N)$	1.3175E+02	1.4833E+02
		$MX(N.m)$	2.2833E+02	2.2975E+02
		$MY(N.m)$	2.9165E+01	3.2490E+01
		$MZ(N.m)$	1.6408E-01	1.6400E-01
1008	$N17$	$FX(N)$	2.9587E+02	3.3579E+02
		$FY(N)$	6.3879E+02	6.7526E+02
		$FZ(N)$	2.6539E+02	2.7947E+02
		$MX(N.m)$	1.8400E-01	1.8500E-01
		$MY(N.m)$	3.2361E+01	3.5570E+01
		$MZ(N.m)$	2.2068E+02	2.2535E+02

Remarks

- displacements of the corners $(N9, N12, N17, N20)$ are identical,
- the reactions to the bearings $(N25, N26, N27, N28)$ are identical,
- the generalized forces are expressed in the total reference.

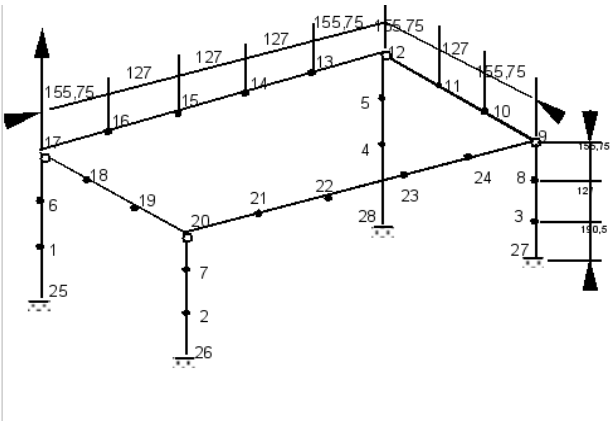
2.3 Bibliographical references

1) NEUBERT V.H. and EZELL W.H.: Dynamic behavior of has foundation like structure. ASME Colloquium one Mechanical Impedance Methods for Mechanical Vibrations, pp. 77-86, 1958.

2) HERCULES: computer code by finite elements for the civil engineer developed by SOCOTEC.

3 Modelization A

3.1 Characteristic of the modelization



Nets $E3$: $N6-N17$
$E4$: $N17-N18$
$E19$: $N17-N16$

Masses of corners : $4.444\,kg$

Intermediate masses : $0.783\,kg$

3.2 Characteristics of the mesh

Many nodes: 28

Number of meshes and types: 52 (28 MECA_POU_D_T and 24 MECA_DIS_T_N)

3.3 Remarks

the modes are standardized with the generalized mass with 1.

The total response is obtained by quadratic combination of the modes, then successively a quadratic combination and a combination of Newmark of the directions of the excitations.

3.4 Values tested: frequencies

Identification	Reference	*Aster*	% difference
Frequency	Mode (Hz)	Frequency (Hz)	
1	110.857	110.913	0.050
2	115.471	115.536	0.056
3	135.936	136.010	0.054
4	213.541	213.706	0.077
5	417.332	417.739	0.098
6	434.813	435.204	0.090
7	464.097	464.539	0.095
8	557.262	557.829	0.102
9	821.746	822.548	0.098
10	847.071	847.859	0.093
11	978.174	979.235	0.108
12	991.842	992.743	0.091
13	1021.669	1022.530	0.084
14	1040.240	1040.970	0.070
15	1056.948	1057.750	0.076
16	1088.861	1089.870	0.093
17	1093.157	1093.910	0.069
18	1107.870	1108.760	0.080

3.5 Values tested with quadratic combination of the directions of the excitations

Identification	Reference	*Aster*	% difference
Displacement:			
$N17 \quad DX(m)$	3.4246E-04	3.4199E-04	-0.168
$DY(m)$	4.3562E-06	4.39290-06	0.842
$DZ(m)$	3.0321E-04	3.0275E-04	-0.152
$DRX(rad)$	3.7031E-04	3.6987E-04	-0.118
$DRY(rad)$	4.7665E-05	4.6261E-05	-0.082
$DRZ(rad)$	5.1104E-04	5.1057E-04	-0.093
Reactions REAC_NODA :			
$N25 \quad FX(N)$	1.2536E+03	1.2536E+03	0.
$FY(N)$	1.2473E+03	1.2635E+03	1.295
$FZ(N)$	1.2196E+03	1.2200E+03	0.029
$MX(N.m)$	3.2474E+02	3.2452E+02	-0.067
$MY(N.m)$	4.1310E+00	4.1283E+00	-0.066
$MZ(N.m)$	3.4846E+02	3.4823E+02	-0.067
Forces EFGE_ELNO :			
$E3 \quad N17 \quad FX(N)$	1.1312E+03	1.1312E+03	0.
$FY(N)$	1.2431E+03	1.2495E+03	0.512
$FZ(N)$	1.0982E+03	1.0981E+03	-0.007
$MX(N.m)$	2.2833E+02	2.282E+02	-0.044
$MY(N.m)$	4.1301E+00	4.1283E+00	-0.056
$MZ(N.m)$	2.2068E+02	2.2056E+02	-0.052
$E4 \quad N17 \quad FX(N)$	1.8813E+02	1.8938E+02	0.665
$FY(N)$	1.0419E+03	1.0423E+03	0.034
$FZ(N)$	1.3175E+02	1.3205E+02	0.229
$MX(N.m)$	2.2833E+02	2.2820E+02	-0.057
$MY(N.m)$	2.9165E+01	2.9187E+01	0.076
$MZ(N.m)$	1.6408E-01	1.8570E-01	13.165
$E19 \quad N17 \quad FX(N)$	2.9587E+02	2.9665E+02	0.264
$FY(N)$	6.3879E+02	6.3900E+02	0.034
$FZ(N)$	2.6539E+02	2.6539E+02	-0.002
$MX(N.m)$	1.8400E-01	1.8607E-01	0.581
$MY(N.m)$	3.2361E+01	3.2366E+01	0.015
$MZ(N.m)$	2.2068E+02	2.2056E+02	-0.053

3.6 Values tested with combination of NEWMARK of the directions of the excitations

Identification	Reference	*Aster*	% difference
Displacement:			
$N17 \quad DX(m)$	3.4265E-04	3.4218E-04	-0.136
$DY(m)$	4.8392E-06	4.9244E-06	1.761
$DZ(m)$	3.0324E-04	3.0278E-04	-0.149
$DRX(rad)$	3.7612E-04	3.7585E-04	-0.072
$DRY(rad)$	5.2602E-05	5.2721E-05	0.226
$DRZ(rad)$	5.2310E-04	5.2267E-04	-0.083
Reactions REAC_NODA :			
$N25 \quad FX(N)$	1.2790E+03	1.2822E+03	0.249
$FY(N)$	1.3868E+03	1.4210E+03	2.467
$FZ(N)$	1.2441E+03	1.2448E+03	0.057
$MX(N.m)$	3.2789E+02	3.2772E+02	-0.050
$MY(N.m)$	4.5579E+00	4.5699E+00	0.263
$MZ(N.m)$	3.5199E+02	3.5211E+02	0.035
Forces EFGE_ELNO :			
$E3 \quad N17 \quad FX(N)$	1.1486E+03	1.1536E+03	0.428
$FY(N)$	1.3793E+03	1.3950E+03	1.135
$FZ(N)$	1.1141E+03	1.1144E+03	0.025
$MX(N.m)$	2.2982E+02	2.2980E+02	-0.010
$MY(N.m)$	4.5580E+00	4.5700E+00	0.261
$MZ(N.m)$	2.2537E+02	2.2546E+02	0.038
E4 N17 FX (N)	2.0079E+02	2.0249E+02	1.071
$FY(N)$	1.0650E+03	1.0672E+03	0.201
$FZ(N)$	1.4833E+02	1.4884E+02	0.344
$MX(N.m)$	2.2975E+02	2.2977E+02	-0.011
$MY(N.m)$	3.2490E+01	3.2625E+01	0.415
$MZ(N.m)$	1.6400E-01	1.8570E-01	13.234
$E19 \quad N17 \quad FX(N)$	3.3579E+02	3.3703E+02	0.369
$FY(N)$	6.7526E+02	6.7606E+02	0.118
$FZ(N)$	2.7947E+02	2.8006E+02	0.210
$MX(N.m)$	1.8500E-01	1.8607E-01	0.581
$MY(N.m)$	3.5570E+01	3.5683E+01	0.317
$MZ(N.m)$	2.2535E+02	2.2542E+02	0.032

- displacements of the corners $(N9, N12, N17, N20)$ are identical,
- the reactions to the bearings $(N25, N26, N27, N28)$ are identical,
- the generalized forces are expressed in the total reference.

4 Summary of the results

One obtains a relatively good agreement between the solution calculated with *Code_Aster* and the solution calculated by HERCULES:

- Frequencies: the variations observed for the first 18 frequencies are weak, lower than 0.11% .
- Displacements: the variations observed are lower than 0.9% if one uses a quadratic combination of the directions of the excitations, and lower than $1.8\ \%$ if one uses a combination of Newmark of the directions of the excitations.
- Forces: the variations observed are lower than 1% , except for the following forces:
- Reactions maximum changes of 2.6%
- Twisting moment in the E19 bar: difference of 13% ; this variation is to be relativized, the value tested being weak compared to the other values.