SDLX301 - Dissymmetrical building with floor-columns subjected to a horizontal excitation

Summary:

It is the three-dimensional study of a building with 3 floors out of 9 columns, embedded at the base of the columns, with unbalance, subjected to a horizontal seismic excitation in displacement. The offset distribution of the masses of the floors makes it possible to break symmetry, to couple the principal geometrical directions and to generate an effect of torsion. The values of reference are obtained with code CASTEM 2000 and the SAMCEF software, which have slightly different methods.

The columns are modelled by beams, and the floors by elements of plane hull. The first eight clean modes are preserved for calculations of modal recombination. Objective: to test the interior displacements, efforts, and the reactions to the embedding of a column for modal recombinations CQC, SRSS, DSC. Precision of the results: comparison between codes. Strong tolerances are allowed for certain computed fields whose values are several weaker orders of magnitude.

1 Problem of reference

This case test is inspired by the report referred to [bib1].

1.1 Geometry

The studied building is composed of 3 floors and 9 columns embedded in the floors.

Section of the columns A : $0.20\,m \times 0.40\,m$
with I

Surface of the columns A : $8.00\,10^{-2}\,m^2$
with I

Inertias of the columns A : $Ix = 2.667\,10^{-4}\,m^4$
with I
(in the total reference mark) $Iy = 1.066\,10^{-3}\,m^4$
$J = 7.45\,10^{-4}\,m^4$

Coefficients of reduced section : $AY = AZ = 1.2$

Thickness of the floors : $0.2\,m$

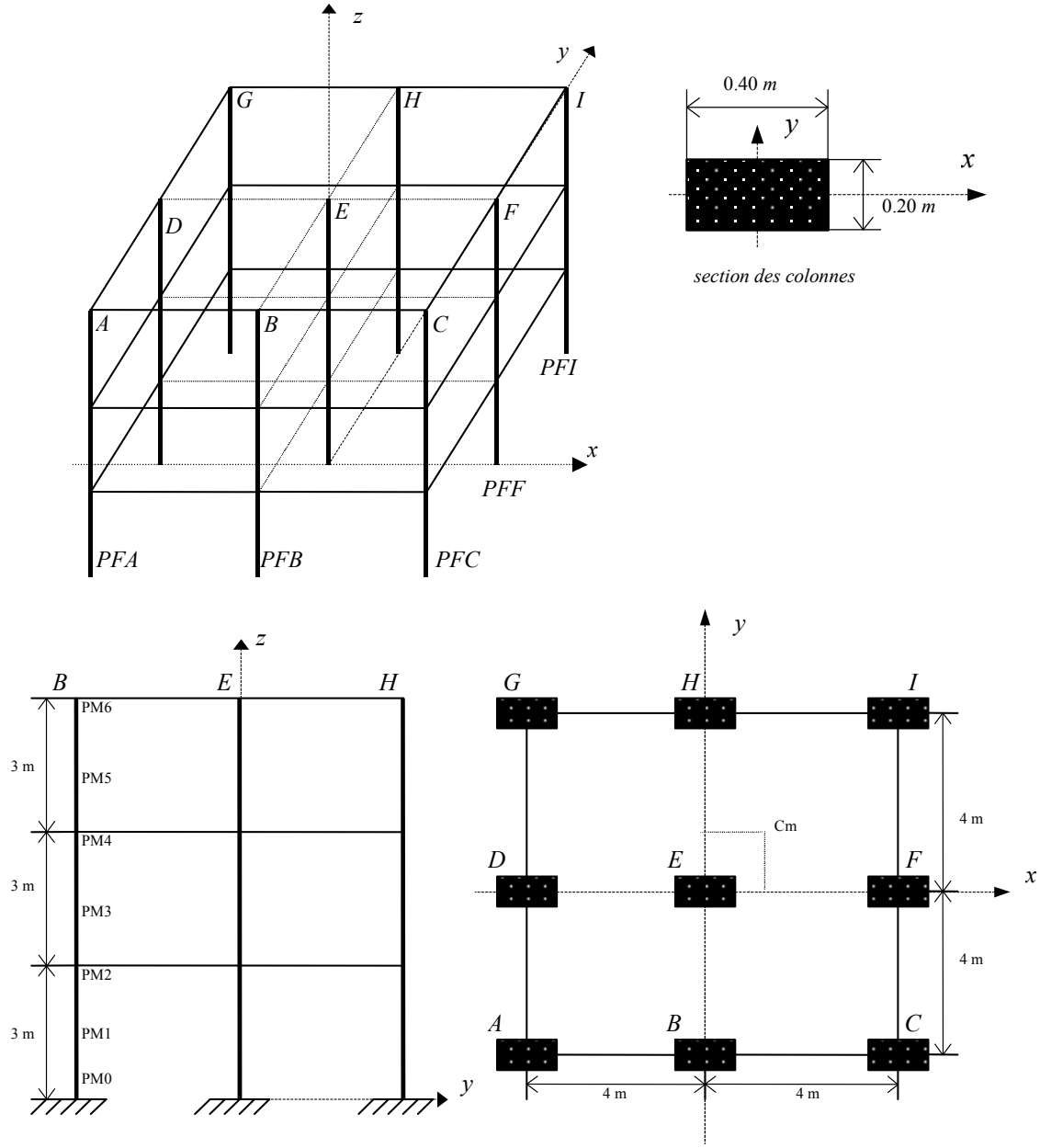


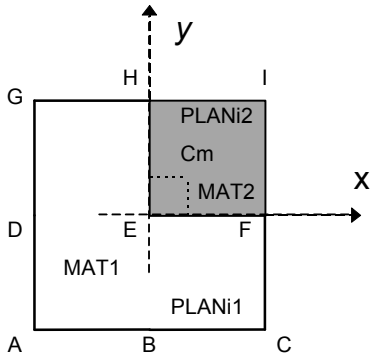
Figure 1-a : Diagram of the building.

1.2 Properties of materials

In order to obtain the centre of mass Cm, excentré compared to the geometrical center of $0,3071\,m$, a material of density $\rho_2 = 1,848\,\rho_1$ is affected with $1/4$ surface of each floor ($PLAN21$, $PLAN22$ and $PLAN23$).

Columns and left $PLAN11$, $PLAN21$ and $PLAN31$ floors:
Young modulus: $E_1 = 4,0\,E+10\,Pa$ Poisson's ratio: $\nu_1 = 0,15$
Density: $\rho_1 = 2500\,kg/m^3$

Parts $PLAN12$, $PLAN22$ and $PLAN32$ floors:
Young modulus: $E_2 = 4,0\,E+10\,Pa$ Poisson's ratio: $\nu_2 = 0,15$
Density: $\rho_2 = 4620\,kg/m^3$



Plancher n° i (groupes de mailles PLANi1 et PLANi2)

Figure 1-b : Diagram of the building.

1.3 Boundary conditions and loading

Boundary condition
The columns are embedded on the level of the foundation.

Loading
The earthquake is applied in the direction x .

The spectrum of answer of oscillators in displacement is obtained by superposition of four spectra of displacement. Each one of these spectra of displacement corresponds to the response of an oscillator to a degree of freedom to the sinewave excitations defined in the table 1-a Ci below:

$$SD(f,\xi)=\sum_{i=1}^{4}\frac{K_i}{4\pi^2 f^2\sqrt{\left(1-\frac{f_i^2}{f^2}\right)^2+4\xi^2\frac{f_i^2}{f^2}}}$$

In particular, the frequencies and depreciation selected are close to the first four modes of the structure.

	Frequency $f_i(Hz)$	**Amplitude** $K_i(m)$	**Damping** ξ
sine 1	1.51	0.15	0.05
sine 2	2.05	0.25	0.05
sine 3	2.34	0.25	0.05
sine 4	4.86	0.30	0.05

Table 1-a : Characteristics of the excitations used.

The neglected modes are represented by a pseudo-mode.

2 Reference solutions

2.1 Method of calculating used for the reference solutions

The calculations taken for reference are carried out with codes CASTEM 2000 and the SAMCEF software. The reference solution is not given by the results of [bib1] because it missed in this reference certain geometrical characteristics and of material to remake with identical the model of the studied structure. Certain data retained in this case test are thus different from those of the report [bib1], which does not allow a comparison of the results.

2.2 Results of reference

- Frequencies calculated with CASTEM 2000 and the SAMCEF software,
- Spectrum of answer in displacement for a damping of $\xi=5\%$,
- Displacements by modal recombination CQC, SRSS, DSC for the column B (calculated by taking of to account the first 8 modes – primarily torsion of the building and inflection of the columns, but the floors are bent little),
- Dynamic and the pseudonym mode for the static correction,
- Efforts with the embedding of the column B and the central column E,
- Interior efforts along the column B.

2.3 Uncertainty on the solution

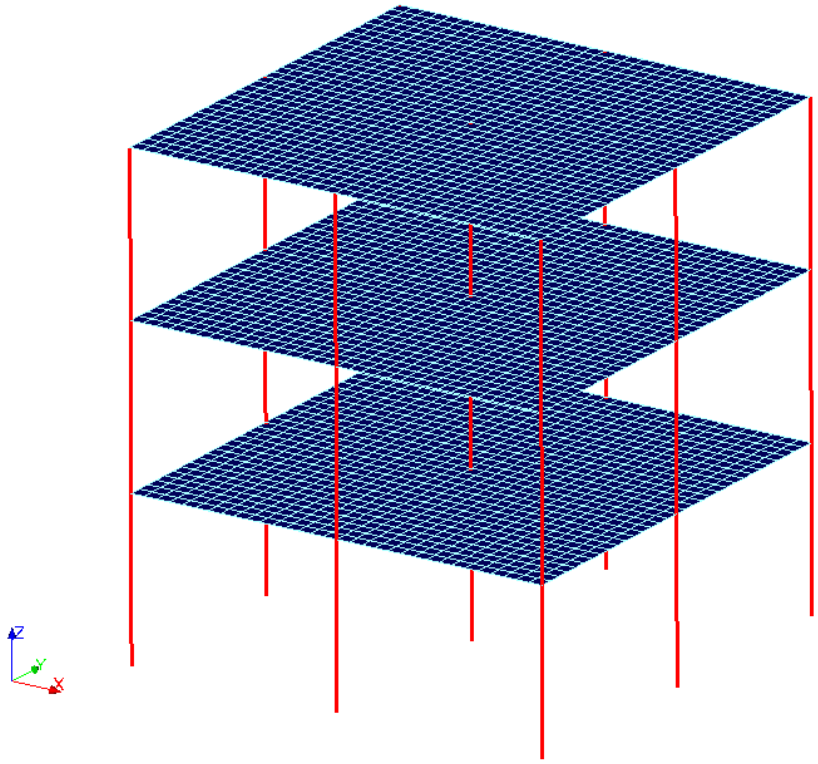
Comparison between codes

2.4 Bibliographical references

[1] MR. MONTAY: Dynamic calculation of the structures in seismic zone. Université libre de Bruxelles, 1982.

3 Modeling With

3.1 Characteristics DE the modeling and of grid



Grid of the model calculated with *Code_Aster* consists of 3357 nodes and 3387 meshs including 135 elements of right beam of Timoshenko (including 12 SEG2 by column, that is to say 108 for the columns) and 3072 elements plates DKT (1024 per floor). In order to ensure the continuity of the degrees of freedom DRZ of clean rotation of the beams with rotation around the normal of the plates (uninsured automatically by *Code_Aster*) elements of beams are added locally at the edge of the plates DKT, on the level as of 27 connections column-floor (group of meshs 'JUNCTIONS' in the command file), to ensure the transmission of rotations DRZ dependent on the movement plan of the plate in rotation in the plan (x, y).

The grid of the model calculated with CASTEM 2000 consists of 3765 nodes and 7368 elements including 108 elements right beam of Timoshenko and 6960 elements of hull DKT.
The grid of the model calculated with the SAMCEF software consists of 3360 nodes and 3180 elements including 108 elements right beam of Mindlin and 3072 elements of hull of Mindlin.

3.2 Results of modeling A

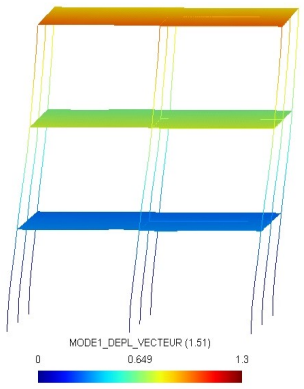
3.2.1 Remarks

For a node i given, effort generalized for the element $i-1$ and for the element i is compared respectively in tables “low” element and “high” element.
The efforts are given in the local reference mark of the elements of beam (principal reference mark of inertia).

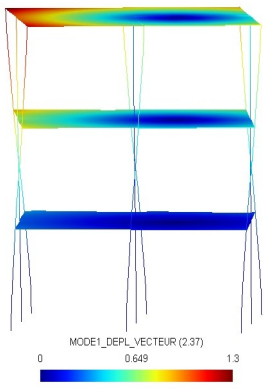
3.2.2 Calculation of the modal base

Eigen frequencies in Hz

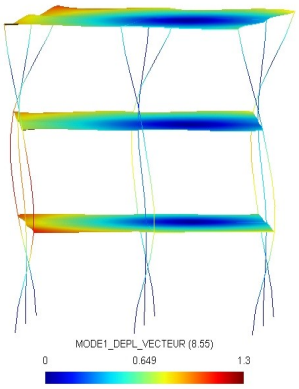
Mode	*Code_Aster*	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
1	1,512	1,512	0,036	1,495	1.11
2	2,052	2,050	0,125	2,014	1.93
3	2,365	2,343	0,916	2,291	3.24
4	4,848	4,859	0,237	4,823	0,522
5	7,488	7,521	0,448	7,415	0.99
6	8,388	8,426	0,456	8,355	0,392
7	8,547	8,543	0,037	8,438	1.30
8	15,185	15,405	1,428	15,186	0,004



Visualization: Mode n° 1;



Mode n° 3;



Mode n° 7.

Effective modal masses in kg

Mode	and direction	*Code_Aster*	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
1	X	2,129E+01	2.300E+01	– 7.451	2.070E+01	2.846
	Y	1,115E+05	1.113E+05	0.127	1.102E+05	1.186
	Z	5,203E-02	6.698E-02	– 22.319	5.816E-02	– 10.531
2	X	9,559E+04	9.365E+04	2.068	9.294E+04	2.847
	Y	1,532E+02	1.817E+02	– 15.689	1.683E+02	– 8.967
	Z	1,002E-02	1.440E-02	– 30.405	1.500E-02	– 33.186
3	X	1,063E+04	1.238E+04	– 14.202	1.201E+04	– 11.509
	Y	4,954E+02	5.181E+02	– 4.399	5.010E+02	– 1.119

	Z	6,074E-03	9.450E-03	– 35.736	8.390E-03	– 27.609
4	X	9,222E-01	9.3722E-01	– 1.606	8.338E-01	10.599
	Y	1,434E+04	1.438E+04	– 0.296	1.438E+04	– 0.247
	Z	1,553E-01	2.066E-01	– 24.850	1.791E-01	– 13.286
5	X	1,606E+04	1.582E+04	1.514	1.594E+04	0.749
	Y	1,537E+01	1.751E+01	– 12.252	1.491E+01	3.096
	Z	3,026E-02	4.386E-02	– 31.012	4.668E-02	– 35.178
6	X	1,829E+02	3.9466E+02	– 53.662	1.901E+03	– 90.380
	Y	3,771E+03	3.622E+03	4.112	1.300E+03	190.089
	Z	1,282E-01	1.809E-01	– 29.145	1.336E-01	– 4.028
7	X	2,064E+03	2.1461E+03	– 3.842	5.331E+02	287.105
	Y	9,264E+01	2.7942E+02	– 66.846	2.627E+03	– 96.474
	Z	1,449E-02	1.222E-02	18.522	2.709E-02	– 46.519
8	X	4,932E+03	4.948E+03	– 0.346	4.974E+03	– 0.851
	Y	1,130E+00	1.121E+00	0.752	1.035E+00	9.143
	Z	5,731E+01	1.5420E+02	– 62.836	5.098E+01	12.411
Office plurality	X	1,2948E+05	1,2936E+05	0.092%	1,2832E+05	0.905%
	Y	1,3037E+05	1,3030E+05	0.053%	1,2919E+05	0.911%
	Z	5,7706E+01	1,5473E+02	-62.706%	5,1448E+01	12,16%

Note:

The standard of error of the modes calculated by the method of Sorensen de Code_Aster is always lower than 10^{-9}.

Note:

The total mass of the building is of $132552\,kg$; the strong orientation according to the modes is due to relative there the less inertia according to there of the columns. Effective modal mass cumulated in the direction x earthquake obtained by Code_Aster represents $97.678\,\%$ total mass.

Note:

The differences between modelings and software are rather strong in the direction z, because she is requested little in these modes.

3.2.3 Spectral response - method CQC

➔ **Displacements - column B (in meter)**

Altitude Z (m)	Component	*Code_Aster*	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
PM1: 1.5	X	1.829E-03	1.717E-03	6,466	1.641E-03	11,439
	Y	2.303E-04	2.276E-04	1,190	1.730E-03	– 86,686
	Z	1.882E-06	1.763E-06	6,728	2.112E-05	– 91,087
PM2: 3.0	X	5.411E-03	5.108E-03	5,935	5.255E-03	2,968
1er floor	Y	5.709E-04	5.679E-04	0,526	3.304E-03	– 82,722
	Z	3.764E-06	3.526E-06	6,729	4.223E-05	– 91,087
PM3: 4.5	X	9.762E-03	9.243E-03	5,608	9.551E-03	2,209
	Y	9.277E-04	9.246E-04	0,331	8.594E-03	– 89,205
	Z	4.750E-06	4.452E-06	6,671	5.540E-05	– 91,426
PM4: 6.0	X	1.409E-02	1.336E-02	5,462	1.381E-02	2,047
2ème floor	Y	1.259E-03	1.255E-03	0,296	1.229E-02	– 89,756
	Z	5.736E-06	5.379E-06	6,633	6.857E-05	– 91,634
PM5: 7.5	X	1.780E-02	1.689E-02	5,352	1.747E-02	1,890
	Y	1.486E-03	1.482E-03	0,224	1.539E-02	– 90,347
	Z	6.014E-06	5.642E-06	6,598	7.376E-05	– 91,846
PM6: 9.0	X	2.085E-02	1.980E-02	5,319	2.057E-02	1,383
3ème floor	Y	1.661E-03	1.657E-03	0,223	1.789E-02	– 90,713
	Z	6.293E-06	5.905E-06	6,567	7.896E-05	– 92,029

➔**Reaction in N and Moment in $N.m$ with the embedding of the column B (group node 'PFE')**

Reaction or moment	*Code_Aster*	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
Fx	3.445E+04	3.325E+04	3,590	3.362E+04	2,460
Fy	1.644E+03	1.629E+03	0,916	2.265E+03	– 27,405
Fz	4.015E+03	3.761E+03	6,729	5.000E+03	– 19,694
MX	2.986E+03	2.975E+03	0,348	4.145E+03	– 27,967
My	8.488E+04	8.135E+04	4,336	8.225E+04	3,208
Mz	1.8460E-03	1.772E-01	– 98,958	2.165E+01	-99.99

➔ **Reaction in N and Moment in $N.m$ with the embedding of the central column E (node group 'PFE')**

Reaction/Moment	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
Fx	5.799E+04	5341E+04	8,552	5.056E+04	14,686
Fy	2.080E+03	2.071E+03	0,428	2.849E+03	– 26,994
Fz	2.471E+02	4.067E+02	– 39,247	1.978E+03	– 87,504
MX	3.419E+03	3.417E+03	0,044	4.728E+03	– 27,691
My	1.202E+05	1.116E+05	7,705	1.074E+05	11,913
Mz	1.842E-03	1.770E-01	– 98,959	2.591E+01	-99.99

➔**Generalized efforts of the column B (in local reference mark)**

Table "low" element (see remark [§ 4.1])

Altitude Z (m)	Component	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
PM1: 1.5	NR (NR)	4.015E+03	3.7618E+03	6,728	5.000E+03	– 19,702
PM1_BAS	Vy (NR)	1.640E+03	1.627E+03	0,770	2.260E+03	– 27,445
	Vz (NR)	3.441E+04	3.323E+04	3,528	3.320E+04	3,634
	MT (N.m)	1.846E-03	1.756E-01	– 98,949	2.160E+01	– 99.99
	Mfy (N.m)	3.325E+04	3.151E+04	5,522	3.320E+04	0,154
	Mfz (N.m)	5.215E+02	5.333E+02	– 2,227	7.650E+02	– 31,835
PM2: 3.0	NR (NR)	4.015E+03	3.761E+03	6,727	4.999E+03	– 19,689
1er floor	Vy (NR)	1.618E+03	1.610E+03	0,482	2.230E+03	– 27,450
PM2_BAS	Vz (NR)	3.420E+04	3.308E+04	3,371	3.286E+04	4,073
	MT (N.m)	1,846 E-03	1.645E-01	– 98,879	2.160E+01	– 99.99
	Mfy (N.m)	1.830E+04	1.824E+04	0,228	1.750E+04	4,603
	Mfz (N.m)	1.925E+03	1.891E+03	1,771	2.620E+03	– 26,542
PM3: 4.5	NR (NR)	2.104E+03	1.976E+03	6,448	2.636E+03	– 20,176
PM3_BAS	Vy (NR)	1.381E+03	1.368E+03	0,952	1.930E+04	– 28,439
	Vz (NR)	3.061E+04	3.000E+04	2,010	2.993E+04	2,265
	MT (N.m)	1.594E-03	1.402E-01	– 98,863	2.570E+01	– 99.99
	Mfy (N.m)	1.434E+03	1.390E+03	3,161	1.440E+03	– 0,385
	Mfz (N.m)	1.295E+02	1.342E+02	– 3,554	1.890E+02	– 31,483
PM4: 6.0	NR (NR)	2.104E+03	1.976E+03	6,450	2.636E+03	– 20,187
2ème floor	Vy (NR)	1.324E+03	1.315E+03	0,618	1.850E+03	– 28,458
PM4_BAS	Vz (NR)	2.993E+04	2.941E+04	1,751	2.931E+04	2,119
	MT (N.m)	1.594E-03	1.049E-01	– 98,481	2.570E+01	– 99.99
	Mfy (N.m)	4.583E+04	4.471E+04	2,480	4.430E+04	3,445
	Mfz (N.m)	2.157E+03	2.126E+03	1,456	2.990E+03	– 27,858
PM5: 7.5	NR (NR)	5.956E+02	5.629E+02	5,817	7.749E+02	– 23,133
PM5_BAS	Vy (NR)	7.279E+02	7.312E+02	– 0,453	1.040E+03	– 30,006
	Vz (NR)	1.935E+04	1.934E+04	0,039	1.934E+04	0,039
	MT (N.m)	9.470E-04	6.137E-02	-98,457	2.660E+01	– 99.99
	Mfy (N.m)	1.234E+04	1.184E+04	4,184	1.210E+04	2,006
	Mfz (N.m)	2.511E+02	2.578E+02	– 2,607	3.800E+02	– 33,921

Table "high" element (see remark [§ 4.1])

Altitude Z (m)	Component	*Code_Aster*	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
PM0: 0.0	NR (NR)	4.015E+03	3.762E+03	6,729	-	-
PM0_HAUT	Vy (NR)	1.644E+03	1.629E+03	0,928	-	-
	Vz (NR)	3.444E+04	3.325E+04	3,593	-	-
	MT (N.m)	1.846E-03	1.770E-01	– 98,957	-	-
	Mfy (N.m)	8.488E+04	8.135E+04	4,336	-	-
	Mfz (N.m)	2.986E+02	2.975E+02	0,348	-	-
PM1: 1.5	NR (NR)	4.015E+03	3.762E+03	6,728	5.000E+03	– 19,702
PM1_HAUT	Vy (NR)	1.640E+03	1.621E+03	1,149	2.250E+03	– 27,123
	Vz (NR)	3.440E+04	3.318E+04	3,683	3.300E+04	4,258
	MT (N.m)	1.846E-03	1.717E-01	– 98,925	2.160E+01	– 99.99
	Mfy (N.m)	3.325E+04	3.150E+04	5,529	3.260E+04	1,997
	Mfz (N.m)	5.215E+02	5.331E+02	– 2,183	7.640E+02	– 31,746
PM2: 3.0	NR (NR)	2.104E+03	1.976E+03	6,454	2.640E+03	– 20,289
1er floor	Vy (NR)	1.419E+03	1.386E+03	2,319	1.950E+03	– 27,233
PM2_HAUT	Vz (NR)	3.103E+04	3.020E+04	2,733	3.010E+04	3,094
	MT (N.m)	1.595E-03	1.540E-01	– 98,965	2.570E+01	– 99.99
	Mfy (N.m)	4.591E+04	4.485E+04	2,354	4.500E+04	2,022
	Mfz (N.m)	1.976E+03	1.935E+03	2,095	2.730E+03	– 27,610
PM3: 4.5	NR (NR)	2.104E+03	1.976E+03	6,453	2.640E+03	– 20,297
PM3_HAUT	Vy (NR)	1.381E+03	1.344E+03	2,739	1.900E+03	– 27,309
	Vz (NR)	3.061E+04	2.974E+04	2,917	2.970E+04	3,062
	MT (N.m)	1.594E-03	1.237E-01	– 98,712	2.570E+01	– 99.99
	Mfy (N.m)	1.434E+03	1.391E+03	3,109	1.440E+03	– 0,385
	Mfz (N.m)	1.295E+02	1.345E+02	– 3,741	1.900E+02	– 31,843
PM4: 6.0	NR (NR)	5.960E+02	5.630E+02	5,847	7.750E+02	– 23,103
2ème floor	Vy (NR)	7.978E+02	7.660E+02	4,147	1.080E+03	– 26,130
PM4_HAUT	Vz (NR)	2.023E+04	1.976E+04	2,358	1.970E+04	2,696
	MT (N.m)	9.477E-04	8.407E-02	– 98,873	2.670E+01	– 99.99
	Mfy (N.m)	1.751E+04	1.762E+04	– 0,636	1.790E+04	– 2,179
	Mfz (N.m)	8.967E+02	8.675E+02	3,363	1.280E+03	– 29,945
PM5: 7.5	NR (NR)	5.956E+02	5.627E+02	5,842	7.750E+02	– 23,143
PM5_HAUT	Vy (NR)	7.279E+02	6.933E+02	4,987	9.930E+02	– 26,693
	Vz (NR)	1.935E+04	1.886E+04	2,561	1.890E+04	2,360
	MT (N.m)	9.470E-04	3.736E-02	– 97,466	2.660E+01	– 99.99
	Mfy (N.m)	1.234E+04	1.184E+04	4,167	1.210E+04	2,006
	Mfz (N.m)	2.511E+02	2.579E+02	– 2,664	3.810E+02	– 34,095

3.2.4 Spectral response - method SRSS

Displacements – column B (in m)

Altitude Z (m)	Component	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
PM1: 1.5	X	1.593E-03	1.4749E-03	7,998	1.40E-03	13,779
N982	Y	2.767E-04	2.795E-04	– 1,050	1.47E-03	– 81,179
	Z	2.253E+06	2.156E-06	4,469	1.95E-05	– 88,447
PM2: 3.0	X	4.714E-03	4.386E-03	7,475	4.46E-03	5,707
1er floor	Y	6.854E-04	6.969E-04	– 1,653	4.12E-03	– 83,364
N1245	Z	4.506E-06	4.312E-06	4,469	3.90E-05	– 88,447
PM3: 4.5	X	8.508E-03	7.939E-03	7,169	8.13E-03	4,655
N1530	Y	1.113E-03	1.133E-03	– 1,797	7.32E-03	– 84,798
	Z	5.684E-06	5.443E-06	4,412	5.12E-05	– 88,898
PM4: 6.0	X	1.229E-02	1.148E-02	7,043	1.18E-02	4,153
2ème floor	Y	1.510E-03	1.538E-03	– 1,842	1.05E-02	– 85,621
N1815	Z	6.862E-06	6.574E-06	4,374	6.33E-05	– 89,159
PM5: 7.5	X	1.552E-02	1.451E-02	6,956	1.49E-02	4,187
N2106	Y	1.780E-03	1.815E-03	– 1,902	1.31e-02	– 86,410
	Z	7.195E-06	6.896E-06	4,338	6.80E-06	– 89,419
PM6: 9.0	X	1.820E-02	1.701E-02	6,944	1.75E-02	3,981
3ème floor	Y	1.990E-03	2.028E-03	– 1,902	1.52E-02	– 86,908
N2355	Z	7.528E-06	7.217E-06	4,303	7.27E-06	– 89,646

Reaction in N and Moment in $N.m$ with the embedding of the column B (node $N758$).

Reaction/Moment	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
Fx	2.999E+04	2.854E+04	5,040	2.883E+04	4,006
Fy	1.977E+03	2.006E+03	– 1,434	1.914E+03	3,336
Fz	4.806E+03	4.600E+03	4,468	4.254E+03	12,973
MX	3.587E+03	3.657E+03	– 1,902	3.510E+03	2,203
My	7.393E+04	6.985E+04	5,830	7.011E+04	5,448
Mz	2.240E-03	1.772E-01	– 98,736	1.989E+01	-99.99

Reaction in N and Moment in $N.m$ with the embedding of the central column E (node $N885$).

Reaction/Moment	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
Fx	5.591E+04	5.094E+04	9,754	4.797E+04	16,558
Fy	2.499E+03	2.545E+03	– 1,818	2.413E+03	3,571
Fz	2.472E+02	4.068E+02	– 39,240	1.972E+03	– 87,462
MX	4.106E+03	4.196E+03	– 2,161	4.008E+03	2,454
My	1.159E+05	1.064E+05	8,897	1.019E+05	13,769
Mz	2.236E-03	1.770E-01	– 98,737	2.288E+01	– 99.99

Generalized efforts of the column B

Table “low” element (see remark [§4.1])

Altitude Z (m)	Component	*Code_Aster*	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
PM1: 1.5	NR (NR)	4.806E+03	4.600E+03	4,469	4.250E+03	13,082
M3158, N982	Vy (NR)	1.972E+03	2.003E+03	– 1,580	1.910E+03	3,233
	Vz (NR)	2.995E+04	2.853E+04	4,979	2.830E+04	5,832
	MT (N.m)	2.240E-03	1.756E-01	– 98,725	1.990E+01	– 99.99
	Mfy (N.m)	2.898E+04	2.706E+04	7,088	2.780E+04	4,261
	Mfz (N.m)	6.254E+02	6.536E+02	– 4,319	6.500E+02	– 3,781
PM2: 3.0	NR (NR)	4.806E+03	4.600E+03	4,467	4.250E+03	13,078
1er floor	Vy (NR)	1.944E+03	1.980E+03	– 1,839	1.890E+03	2,867
M3160, N1245	Vz (NR)	2.977E+04	2.840E+04	4,825	2.800E+04	6,326
	MT (N.m)	2.240E-03	1.646E-01	– 98,639	1.990E+01	– 99.99
	Mfy (N.m)	1.590E+04	1.566E+04	1,513	1.510E+04	5,284
	Mfz (N.m)	2.317E+03	2.334E+03	– 0,746	2.200E+03	5,327
PM3: 4.5	NR (NR)	2.515E+03	2.414E+03	4,184	2.240E+03	12,268
M3162	Vy (NR)	1.664E+03	1.694E+03	– 1,789	1.620E+03	2,703
	Vz (NR)	2.670E+04	2.578E+04	3,551	2.560E+04	4,291
	MT (N.m)	1.935E-03	1.402E-01	– 98,621	2.570E+01	– 99.99
	Mfy (N.m)	1.246E+03	1.152E+03	8,141	1.120E+03	11,269
	Mfz (N.m)	1.564E+02	1.656E+02	– 5,535	1.600E+02	– 2,217
PM4: 6.0	NR (NR)	2.514E+03	2.413E+03	4,183	2.240E+03	12,253
2ème floor	Vy (NR)	1.592E+03	1.626E+03	– 2,151	1.560E+03	2,033
M3164, N1815	Vz (NR)	2.611E+04	2.528E+04	3,308	2.500E+04	4,461
	MT (N.m)	1.934E-03	1.049E-01	– 98,156	2.570E+01	– 99.99
	Mfy (N.m)	3.993E+04	3.840E+04	3,962	3.780E+04	5,635
	Mfz (N.m)	2.598E+03	2.630E+03	– 1,242	2.520E+03	3,085
PM5: 7.5	NR (NR)	7.130E+02	6.904E+02	3,270	6.590E+02	8,197
M3166, N2106	Vy (NR)	8.779E+02	9.099E+02	– 3,521	8.730E+02	0,564
	Vz (NR)	1.693E+04	1.663E+04	1,802	1.650E+04	2,635
	MT (N.m)	1.150E-03	6.137E-02	– 98,128	2.500E+01	– 99.99
	Mfy (N.m)	1.075E+04	1.017E+04	5,675	1.030E+04	4,382
	Mfz (N.m)	3.034E+02	3.201E+02	– 5,243	3.200E+02	– 5,199

Table “high” element (see remark [§ 4.1])

Altitude Z (m)	Component	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
PM0: 0.0	NR (NR)	4.806E+03	4.600E+03	4,468	-	-
M3157, N758	Vy (NR)	1.977E+03	2.006E+03	– 1,429	-	-
	Vz (NR)	2.998E+04	2.854E+04	5,043	-	-
	MT (N.m)	2.240E-03	1.770E-01	– 98,735	-	-
	Mfy (N.m)	7.393E+04	6.986E+04	5,830	-	-
	Mfz (N.m)	3.587E+03	3.657E+03	– 1,902	-	-
PM1: 1.5	NR (NR)	4.806E+03	4.600E+03	4,469	4.250E+03	13,082
M3159, N982	Vy (NR)	1.972E+03	1.995E+03	– 1,176	1.900E+03	3,776
	Vz (NR)	2.995E+04	2.848E+04	5,140	2.810E+04	6,580
	MT (N.m)	2.240E-03	1.717E-01	– 98,696	1.990E+01	– 99.99
	Mfy (N.m)	2.898E+04	2.706E+04	7,096	2.780E+04	4,261
	Mfz (N.m)	6.254E+02	6.533E+02	– 4,276	6.500E+02	– 3,781
PM2: 3.0	NR (NR)	2.515E+03	2.414E+03	4,191	2.240E+03	12,280
1er floor	Vy (NR)	1.709E+03	1.716E+03	– 0,403	1.640E+03	4,231
M3161, N1245	Vz (NR)	2.706E+04	2.595E+04	4,269	2.570E+04	5,304
	MT (N.m)	1.935E-03	1.540E-01	– 98,744	2.570E+01	– 99.99
	Mfy (N.m)	4.009E+04	3.856E+04	3,969	3.850E+04	4,131
	Mfz (N.m)	2.380E+03	2.397E+03	– 0,703	2.300E+03	3,481
PM3: 4.5	NR (NR)	2.515E+03	2.413E+03	4,193	2.240E+03	12,268
M3163, N1530	Vy (NR)	1.664E+03	1.664E+03	– 0,025	1.600E+03	3,987
	Vz (NR)	2.670E+04	2.555E+04	4,469	2.530E+04	5,534
	MT (N.m)	1.935E-03	1.237E-01	-98,437	2.570E+01	– 99.99
	Mfy (N.m)	1.246E+03	1.153E+03	8,084	1.120E+03	11,269
	Mfz (N.m)	1.564E+02	1.659E+02	– 5,734	1.610E+02	– 2,824
PM4: 6.0	NR (NR)	7.134E+02	6.906E+02	3,299	6.590E+02	8,255
2ème floor	Vy (NR)	9.610E+02	9.506E+02	1,087	9.100E+02	5,607
M3165, N1815	Vz (NR)	1.769E+04	1.700E+04	4,099	1.680E+04	5,325
	MT (N.m)	1.150E-03	8.407E-02	– 98,632	2.500E+01	– 99.99
	Mfy (N.m)	1.537E+04	1.516E+04	1,330	1.540E+04	– 0,197
	Mfz (N.m)	1.092E+03	1.1021E+03	– 0,959	1.060E+03	2,974
PM5: 7.5	NR (NR)	7.130E+02	6.902E+02	3,297	6.580E+02	8,362
M3167, N2106	Vy (NR)	8.779E+02	8.644E+02	1,561	8.310E+02	5,647
	Vz (NR)	1.693E+04	1.622E+04	4,345	1.610E+04	5,174
	MT (N.m)	1.149E-03	3.736E-02	– 96,925	2.490E+01	– 99.99
	Mfy (N.m)	1.075E+04	1.017E+04	5,654	1.030E+04	4,382
	Mfz (N.m)	3.034E+02	3.202E+02	– 5,282	3.210E+02	– 5,494

3.2.5 Spectral response - method ROSENBLUETH DSC

For this method, we used a time of 30 seconds simulation.

Displacements - column B (in m)

Altitude Z (m)	Component	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
PM1: 1.5	X	1.858E-03	1.746E-03	6,396	1.643E-3	13,110
N982	Y	2.230E-04	2.197E-04	1,493	1.732E-3	– 87,124
	Z	1.823E-06	1.703E-06	7,048	2.113E-5	– 91,372
PM2: 3.0	X	5.499E-03	5.194E-03	5,864	5.241E-3	4,917
1 er floor	Y	5.528E-04	5.4825E-04	0,827	4.845E-3	– 88,590
N1245	Z	3.646E-06	3.406E-06	7,048	4.225E-5	– 91,370
PM3: 4.5	X	9.919E-03	9.398E-03	5,534	9.560E-3	3,751
N1530	Y	8.983E-04	8.927E-04	0,631	8.603E-3	– 89,558
	Z	4.601E-06	4.300E-06	6,991	5.453E-5	– 91,699
PM4: 6.0	X	1.432E-02	1.359E-02	5,386	1.383E-2	3,548
2ème floor	Y	1.219E-03	1.212E-03	0,596	1.23E-2	– 90,087
N1815	Z	5.557E-06	5.195E-06	6,953	6.861E-5	– 91,901
PM5: 7.5	X	1.808E-02	1.717E-02	5,273	1.748E-2	3,434
N2106	Y	1.439E-03	1.431E-03	0,525	1.54E-2	– 90,657
	Z	5.827E-06	5.450E-06	6,918	7.381E-5	– 92,105
PM6: 9.0	X	2.119E-02	2.013E-02	5,239	2.059E-2	2,892
3rd floor	Y	1.609E-03	1.600E-03	0,524	1.79E-2	– 91,015
N2355	Z	6.097E-06	5.704E-06	6,886	7.901E-5	– 92,283

Reaction in N and Moment in $N.m$ with the embedding of the column B (node $N758$).

Reaction/Moment	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
Fx	3.501E+04	3.381E+04	3,524	3.368E+04	3,938
Fy	1.592E+03	1.572E+03	1,223	2.270E+03	– 29,885
Fz	3.889E+03	3.633E+03	7,050	5.007E+03	– 22,330
MX	2.891E+03	2.872E+03	0,647	4.154E+03	– 30,410
My	8.626E+04	8.273E+04	4,267	8.236E+04	4,738
Mz	1.787E-03	1.772E-01	-98,992	2.170E+01	– 99.99

Reaction in N and Moment in $N.m$ with the embedding of the central column E (node $N885$).

Reaction/Moment	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
Fx	5.827E+04	5.374E+04	8,432	5.061E+04	15,148
Fy	2.014E+03	1.999E+03	0,724	2.855E+03	– 29,471
Fz	2.471E+02	4.067E+02	– 39,252	1.979E+03	– 87,515
MX	3.310E+03	3.298E+03	0,343	4.738E+03	– 30,136
My	1.208E+05	1.122E+05	7,586	1.075E+05	12,386
Mz	1.783E-03	1.770E-01	-98,993	2.601E+01	– 99.99

Generalized efforts of the column B

Table “low” element (see remark paragraph [§4.1])

Altitude Z (m)	Component	*Code_Aster*	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
PM1: 1.5	NR (NR)	3.889E+03	3.633E+03	7,048	5.007E+03	– 22,327
	Vy (NR)	1.588E+03	1.570E+03	1,070	2.266E+03	– 29,938
	Vz (NR)	3.497E+04	3.380E+04	3,461	3.325E+04	5,172
	MT (N.m)	1.786E-03	1.756E-01	– 98,983	2.169E+01	– 99.99
	Mfy (N.m)	3.378E+04	3.204E+04	5,445	3.264E+04	3,507
	Mfz (N.m)	5.050E+02	5.149E+02	– 1,933	7.659E+02	– 34,067
PM2: 3.0	NR (NR)	3.889E+03	3.632E+03	7,047	5.007E+03	– 22,330
1er floor	Vy (NR)	1.566E+03	1.554E+03	0,785	2.235E+03	– 29,911
M3160, N1245	Vz (NR)	3.476E+04	3.364E+04	3,304	3.290E+04	5,646
	MT (N.m)	1.786E-03	1.646E-01	– 98,915	2.167E+01	– 99.99
	Mfy (N.m)	1.861E+04	1.858E+04	0,181	1.752E+04	6,243
	Mfz (N.m)	1.863E+03	1.825E+03	2,075	2.623E+03	– 28,960
PM3: 4.5	NR (NR)	2.039E+03	1.910E+03	6,770	2.641E+03	– 22,799
M3162, N1530	Vy (NR)	1.338E+03	1.321E+03	1,255	1.934E+03	– 30,834
	Vz (NR)	3.109E+04	3.050E+04	1,931	2.997E+04	3,751
	MT (N.m)	1.543E-03	1.402E-01	– 98,900	2.573E+01	– 99.99
	Mfy (N.m)	1.441E+03	1.397E+03	3,154	1.447E+03	– 0,374
	Mfz (N.m)	1.253E+02	1.295E+02	– 3,277	1.900E+02	– 34,035
PM4: 6.0	NR (NR)	2.039E+03	1.910E+03	6,767	2.640E+03	– 22,780
2ème floor	Vy (NR)	1.282E+03	1.270E+03	0,924	1.859E+03	– 31,030
M3164, N1815	Vz (NR)	3.040E+04	2.990E+04	1,675	2.935E+04	3,594
	MT (N.m)	1.542E-03	1.049E-01	– 98.53	2.573E+01	– 99.99
	Mfy (N.m)	4.656E+04	4.546E+04	2,413	4.436E+04	4,969
	Mfz (N.m)	2.089E+03	2.053E+03	1,759	2.999E+03	– 30,340
PM5: 7.5	NR (NR)	5.775E+02	5.441E+02	6,129	7.773E+02	– 25,708
M3166, N2106	Vy (NR)	7.058E+02	7.068E+02	– 0,143	1.045E+03	– 32,457
	Vz (NR)	1.964E+04	1.965E+04	– 0,056	1.937E+04	1,389
	MT (N.m)	9.165E-04	6.137E-02	– 98.51	2.669E+01	– 100.00
	Mfy (N.m)	1.254E+04	1.205E+04	4,116	1.210E+04	3,652
	Mfz (N.m)	2.431E+02	2.488E+02	– 2,314	3.815E+02	– 36,283

Table “high” element (see remark paragraph [§4.1])

Altitude $Z(m)$	Component	Code_Aster	CASTEM 2000	Variation in %	The SAMCEF software	Variation in %
$PM0:0.0$	NR (NR)	3.889E+03	3.633E+03	7,050	–	–
$M3157$, $N758$	Vy (NR)	1.592E+03	1.573E+03	1,229	–	–
	Vz (NR)	3.501E+04	3.382E+04	3,527	–	–
	MT (N.m)	1.787E-03	1.770E-01	– 98,991	–	–
	Mfy (N.m)	8.626E+04	8.273E+04	4,267	–	–
	Mfz (N.m)	2.891E+03	2.872E+03	0,647	–	–
$PM1:1.5$	NR (NR)	3.889E+03	3.633E+03	7,048	5.007E+03	– 22,327
$M3159$, $N982$	Vy (NR)	1.587E+03	1.564E+03	1,451	2.255E+03	– 29,596
	Vz (NR)	3.497E+04	3.375E+04	3,620	3.306E+04	5,773
	MT (N.m)	1.786E-03	1.718E-01	– 98.96	2.168E+01	– 99.99
	Mfy (N.m)	3.378E+04	3.204E+04	5,452	3.263E+04	3,539
	Mfz (N.m)	5.050E+02	5.147E+02	– 1,891	7.655E+02	– 34,033
$PM2:3.0$	NR (NR)	2.039E+03	1.910E+03	7,358	2.641E+03	– 22,791
$M3161$, $N1245$	Vy (NR)	1.374E+03	1.339E+03	2,625	1.374E+03	– - 29,711
	Vz (NR)	3.153E+04	3.071E+04	2,659	3.017E+04	4,493
	MT (N.m)	1.543E-03	1.540E-01	– 98.99	2.572E+01	– 99.99
	Mfy (N.m)	4.663E+04	4.559E+04	2,271	4.51E+04	3,363
	Mfz (N.m)	1.914E+03	1.869E+02	2,396	2.742E+03	– 30,190
$PM3:4.5$	NR (NR)	2.039E+03	1.909E+03	6,775	2.641E+03	– 22,799
$M3163$, $N1530$	Vy (NR)	1.338E+03	1.298E+03	3,049	1.902E+03	– 29,670
	Vz (NR)	3.110E+04	3.023E+04	2,843	2.969E+04	4,734
	MT (N.m)	1.543E-03	1.237E-01	– 97.75	2.573E+01	– 99.99
	Mfy (N.m)	1.442E+03	1.398E+03	3,095	4.440E+04	0,110
	Mfz (N.m)	1.253E+02	1.298E+02	– 3,464	1.904E+02	– 34,174
PM4: 6.0	NR (NR)	5.778E+03	5.442E+02	6,158	7.775E+02	– 25,689
2ème floor	Vy (NR)	7.731E+03	7.402E+02	4,444	1.087E+03	– 28,875
$M3165$, $N1815$	Vz (NR)	2.054E+04	2.008E+04	2,267	1.977E+04	3,887
	MT (N.m)	9.172E-04	8.407E-02	– 98,909	2.670E+01	– 100.00
	Mfy (N.m)	1.776E+04	1.789E+04	– 0,745	1.797E+04	– 1,176
	Mfz (N.m)	8.696E+02	8.388E+02	3,663	1.284E+03	– 32,273
$PM5:7.5$	NR (NR)	5.775E+02	5.440E+02	6,153	7.771E+02	– 25,689
$M3167$, $N2106$	Vy (NR)	7.058E+02	6.704E+02	5,279	9.968E+02	– 29,191
	Vz (NR)	1.964E+04	1.916E+04	2,466	1.891E+04	3,848
	MT (N.m)	9.165E-04	3.736E-02	– 97,547	2.669E+01	– 100.00
	Mfy (N.m)	1.254E+04	1.204E+04	4,099	1.211E+04	3,566
	Mfz (N.m)	2.431E+02	2.490E+02	– 2,369	3.816E+02	– 36,299

4 Results of modeling B

4.1 Remarks

This modeling is carried out to test the option PLAQ_POUT_ORTH key word LIAISON_ELEM order AFFE_CHAR_MECA.

4.2 Characteristics of modeling

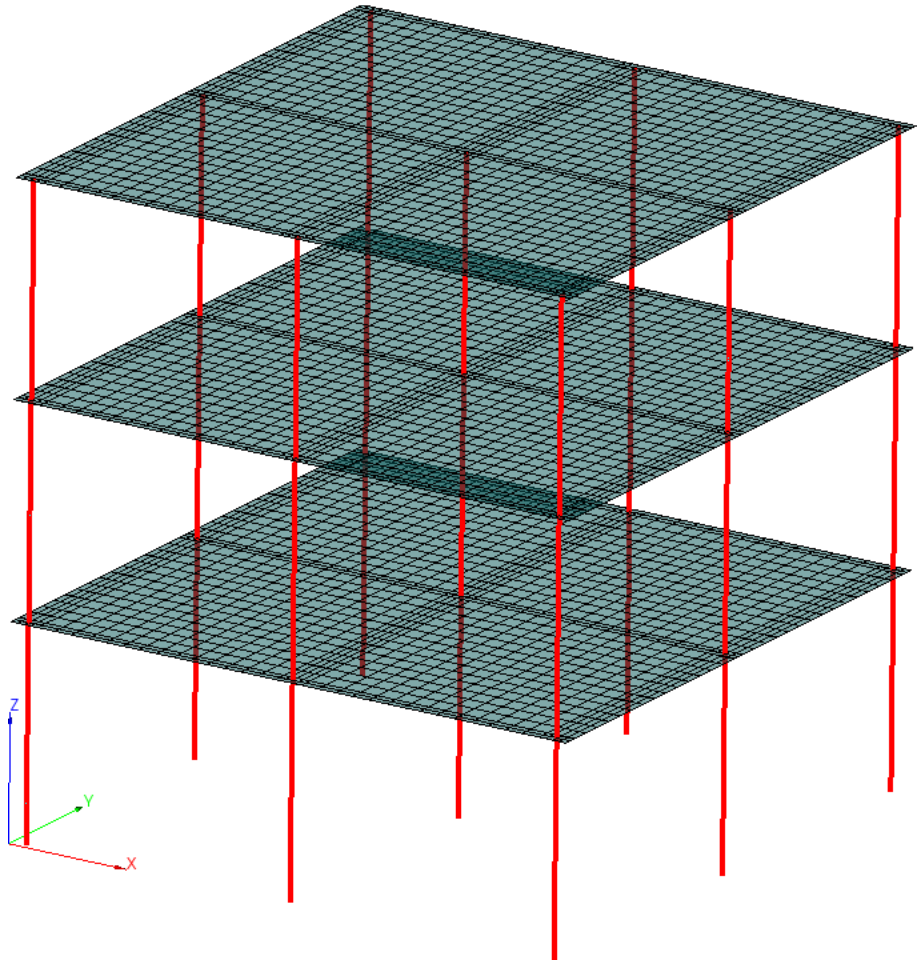


Figure 4-a : Grid of the building.

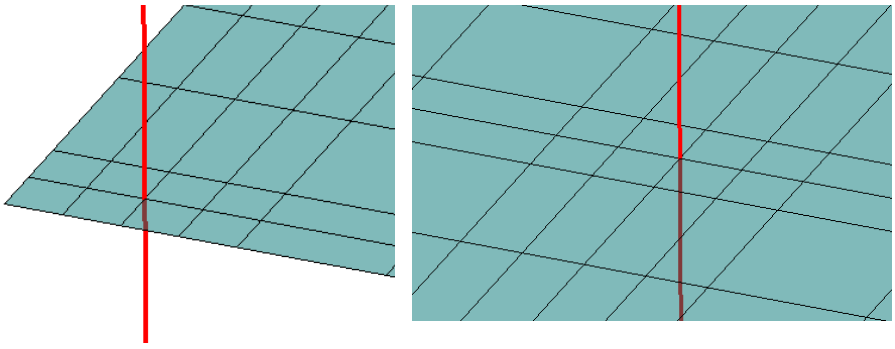


Figure 4-b : Detail of the grid around the posts of bank and exchange.

The grid is a little different from that of modeling A. the distances between centres of the posts are respected, but a edge of a ½ width of post is added to the flagstone. Of another choice of modeling are possible.

4.3 Calculation of the Eigen frequencies

The frequencies are given in Hz .

Mode	Frequency HZ
1	1.83439E+00
2	2.73610E+00
3	3.10015E+00
4	5.51120E+00
5	8.73582E+00
6	8.94514E+00
7	1.00630E+01
8	1.58920E+01

This modeling is a test of nonregression, one thus should not compare the frequencies with those obtained by the other codes.

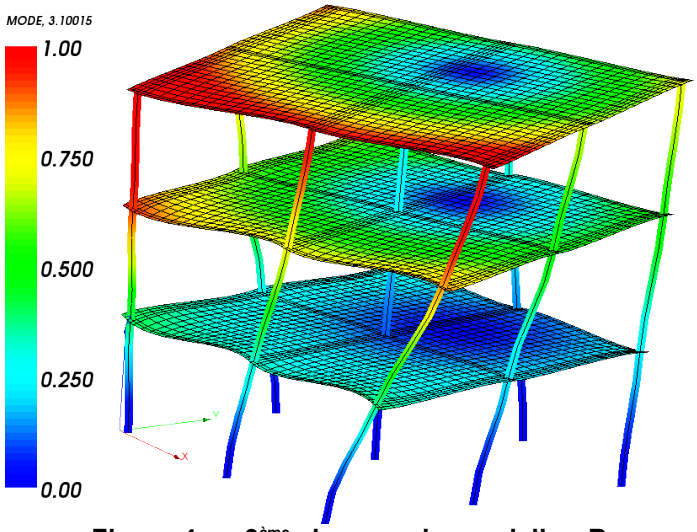


Figure 4-c : 3ème clean mode, modeling B.

5 Summary of the results

Comparison with CASTEM 2000:
The variations on the Eigen frequencies calculated with CASTEM 2000 and Aster are lower than $1,4\ \%$. The double mode was separate in two close modes (6 and 7) of which one is a dominating mode according to the axis y (mode 6) and the other according to x (mode 7); the variation on the effective modal masses (in $\%$) very high according to x for mode 6 and according to y for mode 7, is not relevant being given the weak weight of these directions in the modes considered.

The variations obtained on calculation with the spectral method, for displacements remain overall lower than $8\ \%$, the variations on the reactions to the embedding of the columns B and E are overall lower than $11\ \%$ (without taking account of the moment of reaction according to Z), and the variations on the generalized efforts remain overall lower than $7\ \%$ (without taking account of the torque).
Strong tolerances are allowed for certain computed fields whose values are several weaker orders of magnitude.

Comparison with the SAMCEF software:
The method of resolution adopted in the SAMCEF software is based on the method known as of the ground node. This method consists in binding to a single node all the nodes which are interdependent of the foundation. This node is affected of a mass in translation which is worth 1000 times the mass of the structure. The displacements deferred in the tables are not corrected effects of residual masses which are results also available.

The variations on the Eigen frequencies calculated with the SAMCEF software and Aster are lower than $3,2\ \%$. The type of element of hull used (deformable or not with the shearing action) influence the result, it goes from there in the same way from the smoothness of the grid of the floors. Variations on the Eigen frequencies going until $10\ \%$ were observed by initially taking a coarser grid for the floors, consisted by 345 nodes and 516 elements including 108 elements of right beam of Timoshenko and 408 elements hull DKT. Modes 6 and 7 represent a mode doubles of which the percentage of effective modal mass does not exceed $4\ \%$ in the direction x and $2\ \%$ in the direction y.

The variations obtained on calculation with the spectral method, for displacements in the direction of the excitation remain overall lower than $10,5\ \%$. For the reactions to the embedding of the column B, these variations are overall lower than $30\ \%$. They reach $80\ \%$ for the column E, however for the reaction according to the axis x and moment according to the axis y, they remain lower than $18\ \%$. The reaction of torsion of the columns is not worthless. The variations in connection with the efforts generalized in the direction of the excitation remain overall lower than $26\ \%$. On the other hand, a coupling different between the directions from the excitation introduces important variations on the efforts into the transverse directions with the excitation.
Strong tolerances are allowed for certain computed fields whose values are several weaker orders of magnitude.

Note:
- the form of the function describing the spectrum in displacement strongly depends on the Eigen frequencies f_i for which the peaks of displacement are given. Consequently, a shift of the calculated Eigen frequencies disturbs the seismic answer as starter of the data and does not allow an effective comparison of calculations,
- Dsultats of generalized efforts is expressed in the local reference mark of the beams and is corrected static effects.