SDLX301 - dissymmetrical Building with bottom-columns subjected to a horizontal excitation

Abstract:

It is the three-dimensional study of a building with 3 bottoms 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 bottoms 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 bottoms by shell elements plane. The first eight eigen modes are preserved for computations of modal recombination. Purpose: to test displacements, the internal forces, and the reactions to the fixed support of a column for modal recombinations CQC, SRSS, DSC. Accuracy 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 ratio referred to [bib1].

1.1 Geometry

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

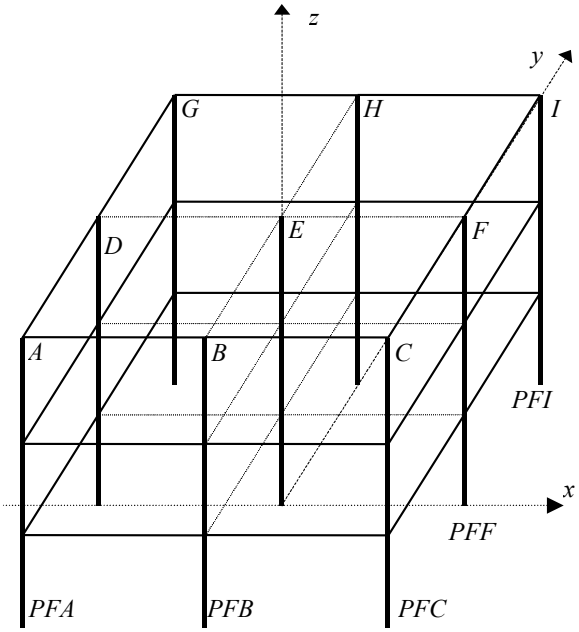
Section of the columns A with I : $0.20\,m \times 0.40\,m$

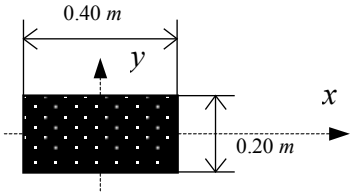
Area of the columns A with I : $8.00\,10^{-2}\,m^2$

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

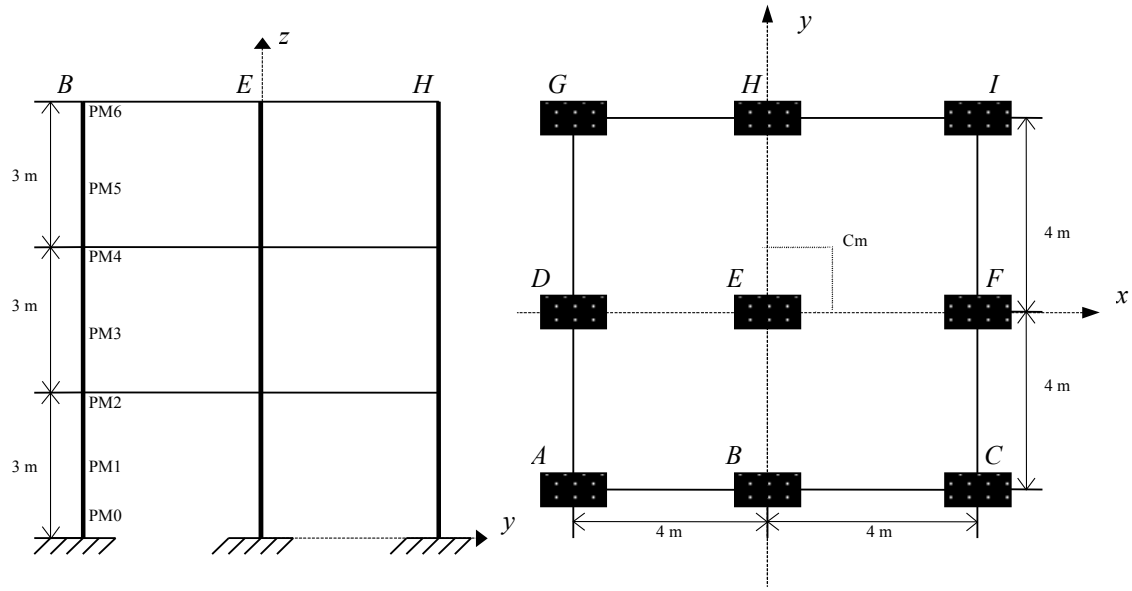
Coefficients of reduced section : $AY = AZ = 1.2$

Thickness of bottoms : $0.2\,m$





section des colonnes



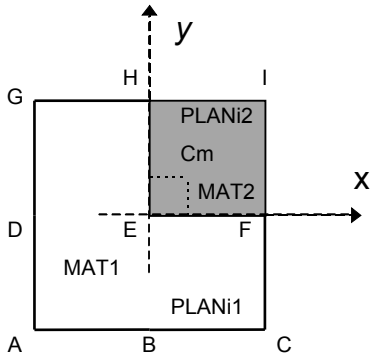
Appear 1-a : Diagram of the building.

1.2 Properties of the materials

In order to obtain the center 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 on $1/4$ surface of each bottom ($PLAN21$, $PLAN22$ and $PLAN23$).

Columns and left $PLAN11$, $PLAN21$ and $PLAN31$ of bottoms:
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 $PLAN32$ of bottoms:
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)

Appear 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 seisme is applied in the direction x .

The response sprectrum of oscillators in displacement is obtained by superposition of four spectrums of displacement. Each one of these spectrums of displacement corresponds to the response of an oscillator with a degree of freedom with the sinewave excitations defined in 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 structure.

	Frequency $f_i(Hz)$	**Amplitude** $K_i(m)$	**Damping** ξ
sine 1	1.51	0.15	0.05
sines 2	2.05	0.25	0.05
sines 3	2.34	0.25	0.05
sines 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 Méthode de calcul used for the reference solutions

the computations 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 studied structure. Certain data retained in this case test are thus different from those of the ratio [bib1], which does not allow a comparison of the results.

2.2 Results of reference

- Frequencies calculated with CASTEM 2000 and the SAMCEF software,
- Response sprectrum in displacement for a damping of $\xi = 5\%$,
- Displacements by modal recombination CQC, SRSS, DSC for the column B (calculated in taking into account the first 8 modes – primarily torsion of the building and bending of the columns, but bottoms are bent little),
- Dynamics and the pseudonym mode for static correction,
- Forces with the fixed support of the column B and the central column E ,
- Internal forces along the column B .

2.3 Uncertainty on the solution

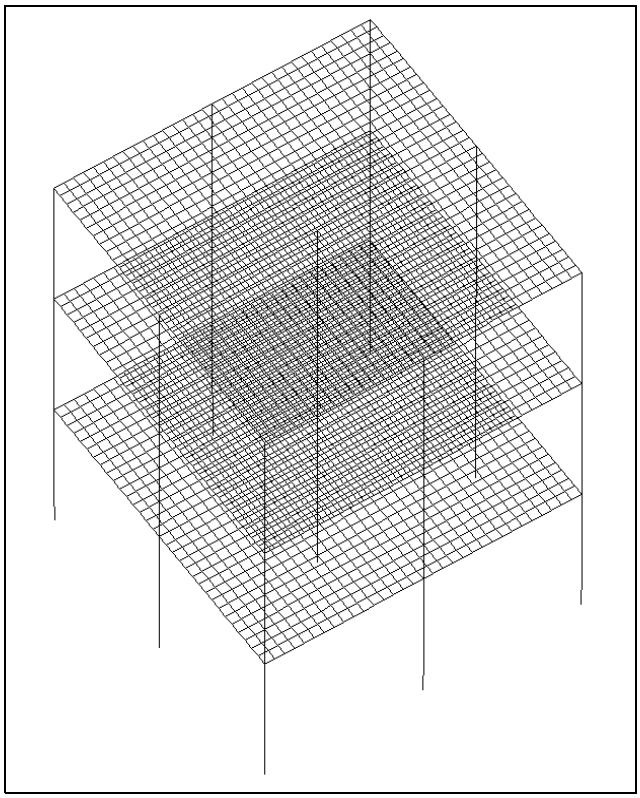
Comparison between bibliographical

2.4 codes References

[1] Mr. MONTAY: Dynamic computation of structures in seismic zone. Université libre de Bruxelles, 1982.

3 Modelization

3.1 Characteristics of the modelization



3.2 Characteristic of the mesh

The mesh of the model calculated with *Code_Aster* consists of 3357 nodes and of 3387 meshes of which 135 beam elements right of Timoshenko (including 12 SEG2 by column, that is to say 108 for the columns) and 3072 elements plates DKT (1024 per bottom). In order to ensure the continuity of clean degrees of freedom DRZ of rotation of the beams with rotation around the norm of the plates (uninsured automatically by *Code_Aster*) of the beam elements are locally added at the edge of plates DKT, the level of the 27 connections column-bottom, to ensure the transmission of rotations DRZ related to the plane motion of the plate in rotation in the plane (x, y).

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

4 Results of the modelization A

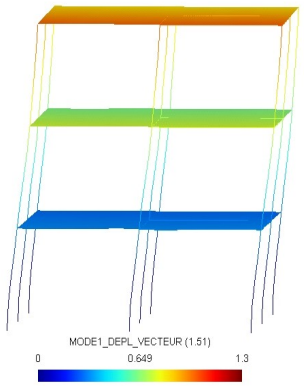
4.1 Remarks

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

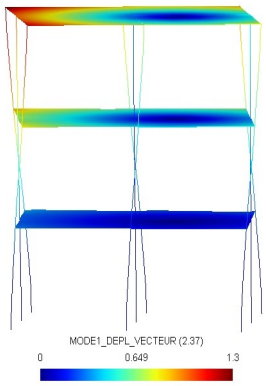
4.2 Computation of modal base

Eigenfrequencies in Hz

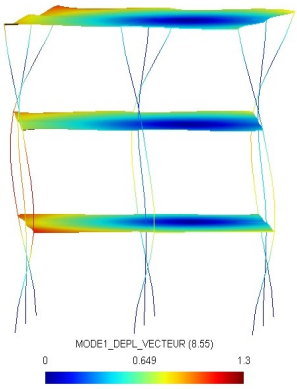
Mode	*Code_Aster*	CASTEM 2000	Variation in %	the SAMCEF software	Variation in %
1	1.512	1.512	0.036	1.495	1.11
2	2.052	2.050	0.125	2.014	1.93
3	2.365	2.343	0.916	2.291	3.24
4	4.848	4.859	0.237	4.823	0.522
5	7.488	7.521	0.448	7.415	0.99
6	8.388	8.426	0.456	8.355	0.392
7	8.547	8.543	0.037	8.438	1.30
8	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 error norm 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 directional sense according to the modes is due to relative there the less inertia according to there of the columns. The effective modal mass cumulated in the direction x of the seisme obtained by Code_Aster represents $97.678\,\%$ total mass.

Note:

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

4.3 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
N982	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
the 1st bottom	Y	5.709E-04	5.679E-04	0.526	3.304E-03	– 82.722
N1245	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

N1530	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
the 2nd bottom	Y	1.259E-03	1.255E-03	0.296	1.229E-02	– 89.756
N1815	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
N2106	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
the 3rd bottom	Y	1.661E-03	1.657E-03	0.223	1.789E-02	– 90.713
N2355	Z	6.293E-06	5.905E-06	6.567	7.896E-05	– 92.029

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

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 fixed support of the central column E (node $N885$)

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 Forces of the column B (in local coordinate system)

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	N (N)	4.015E+03	3.7618E+03	6.728	5.000E+03	– 19.702
M3158, N982	Vy (N)	1.640E+03	1.627E+03	0.770	2.260E+03	– 27.445
	Vz (N)	3.441E+04	3.323E+04	3.528	3.320E+04	3.634
	MT (N.m) 1.846	E-03 1.756	E-01 –	98.949 2.160	E+01 –	99.99 Mfy
	(N.m) 3.325	E+04 3.151	E+04 5.522	3.320	E+04 0.154	Mfz (
	N.m) 5.215E+02	5.333E+02	– 2.227	7.650E+02	– 31.835	PM2: 3.0
N (N) 4.015	E+03	3.761E+03	6.727 4.999	E+03	– 19.689	the 1st bottom
Vy (N) 1.618	E+03	1.610E+03	0.482 2.230	E+03	– 27.450	M3160, N
1245 Vz (N) 3.420	E+04	3.308E+04	3.371 3.286	E+04	4.073 MT	(N.m) 1.846
	E-03	1.645 E-01	– 98.879 2.160	E+01 –	99.99 Mfy	(N.m) 1.830
	E+04 1.824	E+04 0.228	1.750E+04	4.603	Mfz (N.m) 1.925	E+
	03 1.891E+	03 1.771 2.620	E+03 –	26.542	PM3:	4.5 N (N)
2.104E+03 1.976	E+	03 6.448 2.636	E+03 –	20.176	M3162,	N1530 Vy (
N) 1.381E+03	1.368E+	03 0.952 1.930	E+04 –	28.439	Vz (N)	3.061E+04
	3.000E+	04 2.010 2.993	E+04 2.265	MT	(N.m) 1.594	E-03
	1.402E-	01 – 98.863	2.570E+01	– 99.99 Mfy	(N.m) 1.434	E+03 1.390
	E+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 N (N)	2.104E+03
1.976E+03	6.450	2.636E+03	– 20.187	the 2nd	bottom Vy	(N) 1.324
E+03	0.618	1.850E+03	– 28.458	M3164,	N1815 Vz	(N)

1.315E+03						2.993E
+04 2.941E+04	1.751	2.931E+04	2.119 MT (	N.m) 1.594	E-03 1.049	E
	01 – 98.481	2.570E+	01 – 99.99	Mfy (N.m) 4.583	E+04 4.471	E+04 2.480
	4.430E	+04 3.445	Mfz (N.m) 2.157	E+03	2.126E+03	1.456
	2.990E+03	– 27.858	PM5: 7.5	N (N	) 5.956E+02	5.629E+ 02
5.817 7.749	E+02	– 23.133	M3166, N2106	Vy	(N) 7.279	E+02 7.312
E+02 – 0.453	1.040E	+03 – 30.006	Vz (N)	1.935E+ 04	1.934E+04	0.039 1.934
	E+04	0.039 MT	(N.m) 9.470E-	04 6.137	E-02	-98.457
	2.660E	+01 – 99.99	Mfy (N.m) 1.234	E+04 1.184	E+04 4.184	1.210
	E+04 2.006	Mfz (N.m) 2.511	E+02 2.578	E+02	– 2.607	3.800
	E+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 % PM*	0: 0.0 N	(N) 4.015E+03	3.762	E+03 6.729 -
- M3157 N	758 Vy	(N) 1.644	E+03 1.629	E+03 0.928		
- - Vz (N)	3.444E+	04 3.325E+	04 3.593 -	- MT	(N.m)	1.846
	E	03 1.770E	– 01 – 98.957		-	-
	Mfy (N.m) 8.488	E+04 8.135	E+04 4.336	- - Mfz (N.m)	2.986	
	E+02 2.975	E+02 0.348	- - PM1	: 1.5		N
	(N) 4.015E	+03 3.762E	+03 6.728	5.000E	+03	
– 19.702 M	3159,	N982 Vy (N	) 1.640E+03	1.621	E+03 1.149	2.250E+ 03
– 27.123	Vz (N)	3.440E+04	3.318E+04	3.683	3.300E+04	4.258 MT (
	N.m) 1.846	E-03 1.717	E-01 –	98.925	2.160E+	01 –
	99.99 Mfy	(N.m) 3.325E+04	3.150E+04	5.529 3.260	E+04 1.997	Mfz (N.m)
	5.215E+02	5.331E+02	– 2.183 7.640	E+	02 – 31.746	PM2
	: 3.0 N	(N) 2.104E	+03 1.976E	+03 6.454	2.640E+03	– 20.289
the 1st Vy	bottom	(N) 1.419E	+03 1.386E	+03 2.319	1.950E	+03 – 27.233
M3161, N1245	Vz	(N) 3.103E	+04 3.020E	+04 2.733	3.010E	+04 3.094
MT (N.m) 1.595E-	03 1.540	E-01	– 98.965	2.570E	+01 – 99.99	Mfy
	(N.m) 4.591	E+04 4.485E+	04 2.354 4.500	E+04 2.022	Mfz (N.m)	1.976E+ 03
	1.935E+03	2.095 2.730	E+03 –	27.610	PM3: 4.5	N (N
	) 2.104E+03	1.976E+03	6.453 2.640	E+03	– 20.297	M3163, N
1530 Vy (N)	1.381	E+03 1.344	E+03 2.739	1.900	E+03 – - 27.309	Vz (
N) 3.061E+04	2.974E+	04 2.917 2.970	E+04 3.062	MT	(N.m) 1.594	E-03 1.237
	E-01	– 98.712	2.570E+01	– 99.99	Mfy (N.m)	1.434
	E+03 1.391	E+03 3.109	1.440E+03 –	0.385 Mfz	(N.m) 1.295E	+02 1.345
	E+02 – 3.741	1.900E	+02 – 31.843	PM	4: 6.0 N	(N) 5.960
	E+02 5.630	E+02 5.847	7.750E+02	– 23.103	the 2nd Vy	bottom
(N) 7.978E	+02 7.660	E+02 4.147	1.080E	+03 –	26.130 M3165	, N1815
Vz (N) 2.023E+	04 1.976	E+04 2.358	1.970E+04	2.696	MT (N.m) 9.477	E-04
8.407E-02 –	98.873	2.670E+01	– 99.99	Mfy (	N.m) 1.751E+04	1.762
	E+04 –	0.636 1.790E	+04 – 2.179	Mfz (N.m) 8.967	E+02 8.675	E+02 3.363
	1.280	E+03 – 29.945	PM5	: 7.5 N (	N) 5.956E+	02 5.627E

	+02 5.842	7.750E+02	– 23.143	M3167,	N2106 Vy	(N) 7.279E
+02 6.933E+	02 4.987	9.930E+	02 – 26.693	Vz	(N) 1.935E	+04 1.886E
+04 2.561 1.890	E+04	2.360 MT (	N.m) 9.470E-	04 3.736	E-02	– 97.466
	2.660E+	01 – 99.99	Mfy (N.m) 1.234	E+	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	spectral	Response	- method	SRSS	Displace ments
		– column	(in)	Altitude	Z (m) Componen t	Code_As ter

4.4 CASTEM 2000 Variation in % the SAMCEF software

Variation in % PM1: 1.5 B X 1.593 m

E-03 1.4749E-	03 7.998	*1.40E-03*	13.779 N982	Y 2.767E-04	2.795	E-04 – 1.050
1.47E-	03	– 81.179	Z 2.253E+06 2.156	E	06 4.469	1.95E-
05 –		88.447 PM2	: 3.0 X 4.714	E-03 4.386	E-03	7.475 4.46
	E	03 5.707	the 1st bottom	Y 6.854	E-04 6.969	E-04
– 1.653 4.12		E-03 – 83.364	N1245	Z 4.506	E-06 4.312	E
06 4.469 3.90	E	05 – 88.447	PM3: 4.5	X 8.508	E-03 7.939	E-03 7.169
8.13		E-03 4.655	N1530 Y 1.113	E	03 1.133E-	03 – 1.797
7.32E-	03	– 84.798 Z	5.684E-06	5.443	E-06 4.412	5.12
E-05	–	88.898 PM4	: 6.0 X 1.229	E-02	1.148E-02	7.043 1.18
		E-02 4.153	the 2nd bottom	Y	1.510E-03	1.538E-
03 – 1.842	1.05	E-02 –	85.621 N1815	Z 6.862	E-06 6.574	E
06 4.374 6.33	E	05 – 89.159	PM5: 7.5	X 1.552	E-02 1.451	E-02 6.956
1.49		E-02 4.187	N2106 Y 1.780	E	03 1.815E-	03 – 1.902
1.31e-	02	– 86.410 Z	7.195E-06	6.896	E-06 4.338	6.80
E-06	–	89.419 PM6	: 9.0 X 1.820	E-02	1.701E-02	6.944 1.75
		E-02 3.981	the 3rd bottom	Y	1.990E-03	2.028E-
03 – 1.902	1.52	E-02 –	86.908 N2355	Z 7.528	E-06 7.217	E
06 4.303 7.27	E	06 – 89.646	Reaction	in and Moment	in with	the fixed support
		of the column	(node	). Reaction	/Moment	Code_Aster

CASTEM 2000 N Variation in % $N.m$ the SAMCEF software Variation in % Fx 2.999E+04 2.854 B E+04 5.040 $N758$

2.883E+04 4.006	*Fy 1.977E+*	03 2.006E+03	– 1.434 1.914	E+03	3.336 Fz 4.806
	E+03 4.600	E+03 4.468	4.254	E+03 12.973	MX 3.587
	E+03 3.657	E+03 – 1.902	3.510	E+03 2.203	My 7.393
	E+04 6.985	E+04 5.830	7.011	E+04 5.448	Mz 2.240
	E-03 1.772	E-01 –	98.736	1.989E+01	-99.99
Reaction	in	and	in	with the	

		Moment		fixed support	
	of the central	column	(node)	. Reaction	/ Moment

Code_Aster CASTEM N 2000 Variation $N.m$ in % the SAMCEF software Variation in % Fx 5.591E+04 5.094 E E+04 9.754 $N885$

4.797E+04 16.558	***Fy 2.499E***	**+03 2.545E+03**	**– 1.818 2.413**	**E+03**	**3.571 Fz 2.472**
	E+02 4.068	E+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 2.236
	E-03 1.770	E-01	– 98.737	2.288E+01	– 99.99
	generalized Forces		of	the column	Table
	“low	” element (	see remark	[§4.1	]) Altitude

Z (m) Component Code_Aster CASTEM B

2000 Variation in % the SAMCEF software Variation in % PM1: 1.5 N (N) 4.806

E+03 4.600E	+03 4.469 4.250	*E+03 13.082*	M3158,	N982 Vy (N)	1.972E+	03 2.003E+03
– 1.580 1.910	E+	03 3.233 Vz	(N) 2.995	E+04	2.853E+04	4.979 2.830
E+04 5.832	MT (	N.m) 2.240E-	03 1.756E	– 01 –	98.725 1.990	E+01
	– 99.99	Mfy (N.m)	2.898E+04	2.706E	+04 7.088	2.780E
	+04 4.261	Mfz (N.m) 6.254	E+02 6.536E	+02 – 4.319	6.500E+	02 – 3.781
	PM2:	3.0 N (N)	4.806E+03	4.600E	+03 4.467	4.250E
	+03 13.078	the 1st Vy	bottom (N)	1.944E+ 03	1.980E+03	– 1.839
1.890E+03	2.867	M3160, N1245	Vz (N)	2.977	E+04 2.840	E+04 4.825
2.800E+04	6.326	MT (N.m) 2.240	E-03 1.646	E-01	– 98.639	1.990
E+01 – 99.99	Mfy (N.m)	1.590E+04	1.566E+04	1.513	1.510E+04	5.284
	Mfz (N.m) 2.317	E+03 2.334	E+03 – 0.746	2.200E	+03 5.327	PM3: 4.5
	N (N) 2.515	E+03 2.414	E+03 4.184	2.240	E+03 12.268	M
	3162 Vy (N	) 1.664E+03	1.694E+03	– 1.789	1.620E+03	2.703
Vz (N) 2.670	E+04	2.578E+04	3.551 2.560	E+04	4.291 MT	(N.m) 1.935
E	03 1.402	E-01 –	98.621 2.570	E+01 –	99.99 Mfy	(N.m) 1.246
	E+03	1.152E+03	8.141 1.120	E+03	11.269 Mfz	(N.m)
	1.564E+02	1.656E+02 –	5.535 1.600	E+02 – 2.217	PM4	: 6.0 N (
	N) 2.514E+	03 2.413E+	03 4.183 2.240	E+	03 12.253	the 2nd bottom
	Vy	(N) 1.592	E+03 1.626	E+03 – 2.151	1.560	E+03 2.033
M3164, N1815	Vz	(N) 2.611	E+04 2.528	E+04 3.308	2.500	E+04 4.461
MT (N.m) 1.934	E-03	1.049E-01	– 98.156	2.570E+	01 – 99.99	Mfy
(N.m) 3.993E+04	3.840E+	04 3.962 3.780	E+04 5.635	Mfz	(N.m) 2.598	E+03
	2.630E+03	– 1.242 2.520	E+03 3.085	PM5: 7.5	N (N) 7.130	E+02
	6.904E+02	3.270 6.590	E+02 8.197	M3166	, N2106 Vy	(N)
	8.779E+02	9.099E+02	– 3.521 8.730	E+02	0.564 Vz (	N) 1.693
E+04 1.663	E+04	1.802 1.650	E+04 2.635	MT (	N.m) 1.150E-	03 6.137
E-02 –	98.128	2.500E+01	– 99.99 Mfy	(N.m) 1.075	E+04 1.017	E+04
	5.675	1.030E+04	4.382 Mfz	(N.m) 3.034	E+02 3.201	E+02
	– 5.243	3.200E+02 –	5.199 Table	“	high”	elemen t (see

remark	[§ 4.1	]) Altitude	Z (m	) Component	Code_Aster	
CASTEM	2000	Variation in	% the SAMCEF software	Variation in	% PM0:	

0.0 N (N) 4.806E+03 4.600E+03 4.468 - - M3157, N758 Vy (

N) 1.977E+03 2.006	**E+03 –**	***1.429 - - Vz***	**(N) 2.998E**	**+04 2.854E+04**	**5.043**	**- - MT (N.m) 2.240**
E-03	1.770E	– 01 – 98.735	- -	Mfy (N.m)	7.393	
E+04 6.986	E+04 5.830	- - Mfz	(N.m) 3.587	E+03 3.657	E	+03
	– 1.902	- - PM	1: 1.5 N	(N) 4.806		
	E+03 4.600	E+03 4.469	4.250E+03 13.082	M3159	,	N982
	Vy (N)	1.972E+03	1.995E+03	– 1.176		1.900
	E+03 3.776	Vz (N	) 2.995E+04	2.848E+	04	5.140
2.810E	+04 6.580	MT (N.m)	2.240E-03	1.717	E-01 –	98.696
1.990E+01 –	99.99	Mfy (N.m) 2.898	E+04 2.706	E+04 7.096	2.780	E+04 4.261
	Mfz	(N.m) 6.254	E+02 6.533	E+02 –	4.276 6.500	E+02
	– 3.781	PM2: 3.0	N (N) 2.515	E+03 2.414	E+03 4.191	2.240E +03
	12.280 the 1st	bottom	Vy (N) 1.709	E+	03 1.716E+	03 –
	0.403 1.640	E+03 4.231	M3161, N	1245 Vz (	N) 2.706E+	04 2.595E
+04 4.269 2.570	E+	04 5.304 MT	(N.m) 1.935	E-03	1.540E-	01 – 98.744
2.570E+	01 – 99.99	Mfy (	N.m) 4.009E+04	3.856E+	04 3.969 3.850	E+
04 4.131 Mfz	(N.m) 2.380	E+03 2.397	E+03 – 0.703	2.300	E+03 3.481	PM
	3: 4.5	N (N) 2.515	E+03 2.413E+	03 4.193 2.240	E+03 12.268	M3163
	, N1530	Vy (N) 1.664	E+03 1.664	E+03	– 0.025	1.600E
	+03 3.987	Vz (N) 2.670	E+04 2.555	E+04 4.469	2.530E	+04 5.534
MT (N.m) 1.935	E	03 1.237	E-01 -98.437	2.570	E+01 –	99.99
Mfy (N.m) 1.246	E+03 1.153	E+03 8.084	1.120E	+03 11.269	Mfz (N.m) 1.564	E+
	02 1.659	E+02 – 5.734	1.610	E+02 –	2.824 PM	4: 6.0
	N (N)	7.134E+02 6.906	E+02 3.299	6.590E	+02 8.255	the 2nd Vy
	bottom (	N) 9.610E+	02 9.506E+	02 1.087	9.100E+	02 5.607
	M3165, N	1815 Vz (N	) 1.769E+04	1.700E+	04 4.099 1.680	E+04
5.325 MT (N.m)	1.150	E-03 8.407	E-02 –	98.632	2.500E+	01 –
99.99 Mfy (N.m) 1.537	E+04	1.516E+04	1.330 1.540	E+04	– 0.197	Mfz (N.m)
1.092E+03 1.1021	E+03	– 0.959	1.060E+03	2.974	PM5: 7.5	N (N
	) 7.130E+	02 6.902E+02	3.297 6.580	E+02 8.362	M3167, N2106	Vy (N
	) 8.779E+02	8.644E+02	1.561 8.310	E+02	5.647 Vz	(N)

						1.693
	E+04 1.622	E+04 4.345	1.610E+04	5.174 MT	(N.m) 1.149E	– 03
3.736E-02	– 96.925	2.490	E+01 – 99.99	Mfy	(N.m) 1.075	E+04 1.017
E+04 5.654	1.030	E+04 4.382	Mfz (N.m) 3.034	E+02	3.202E+02	– 5.282
	3.210	E+02 –	5.494 spectral		Response	- method
	ROSENBLU ETH	DSC	For this method	, we		used
	a time of	30	seconds simulation		. Displacem ents	
	- column	(in) Altitude	Z	(m) Compon ent	Code_Ast er	CASTE M

4.5 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 2.197

E-04 1.493 1.732E-3 – B 87.124 m

Z 1.823E-06	**1.703E-06**	***7.048 2.113***	**E-5 – 91.372**	**PM2:**	**3.0 X**	**5.499E-03**
5.194E-03	5.864	5.241E-	3 4.917 the 1st	bottom	Y 5.528	E
04 5.4825		E-04 0.827	4.845E-	3 –	88.590 N1245	Z 3.646E
	–	06 3.406E-	06 7.048 4.225	E	5 – 91.370	PM3: 4.5
X 9.919E	–	03 9.398E-	03 5.534 9.560	E	3 3.751 N1530	Y
8.983 E – 04 8.927	E	– 04 0.631	8.603E-3 –	89.558	Z 4.601E-	06 4.300
E-06	6.991	5.453E-	5 – 91.699	PM4	: 6.0 X 1.432	E-02
1.359E-02	5.386	1.383E-	2 3.548 the 2nd	bottom	Y 1.219	E
03 1.212		E-03 0.596	1.23E-2	– 90.087	N1815 Z	5.557E-
	06	5.195E-06	6.953 6.861	E-5	– 91.901 PM	5: 7.5
X 1.808E-	02	1.717E-02	5.273 1.748	E-2	3.434 N2106	Y 1.439
E 03 1.431E	–	03 0.525 1.54	E-2 – 90.657		Z 5.827E-	06 5.450E
– 06	6.918	7.381E-	5 – 92.105	PM6	: 9.0 X 2.119	E-02 2.013
E-02	5.239	2.059E-	2 2.892 the 3rd	bottom	Y 1.609	E
03 1.600		E-03 0.524	1.79E-2 –	91.015	N2355 Z	6.097E-
	06	5.704E-06	6.886 7.901	E-5	– 92.283 Reaction	in
and Moment		in with the fixed support		of	the column (node	
). Reaction/Moment in %		Code_Aster	CASTEM 2000	Variation	in % the SAMCEF software	Variation
	Fx	3.501E+04	3.381E+04 3.524	3.368	E+04 3.938	Fy 1.592

E+03 1.572E+03 N 1.223 2.270E $N.m$ +03 – 29.885 Fz 3.889E+03 3.633E+03 B 7.050 $N758$ 5.007

E+03 – 22.330	***MX 2.891E+03***	**2.872E+03**	**0.647 4.154E**	**+03 –**	**30.410 My 8.626**
	E+04 8.273	E+04 4.267	8.236	E+04 4.738	Mz 1.787
	E-03 1.772	E-01 -98.992		2.170E+01	– 99.99
Reaction	in	and Moment	in with	the fixed support	of
	the central	column	(node	). Reaction	/Moment
Code_Aster		CASTEM 2000	Variation	in % the SAMCEF	Variation

				software	
	in % Fx	E+04	E+04	5.061	E+04
	5.827	5.374	8.432		15.148

Fy 2.014E+03 N 1.999E+03 0.724 $N.m$ 2.855E+03 – 29.471 Fz 2.471E+02 4.067E+ E 02 – 39.252 $N885$

1.979E+03 – 87.515	***MX 3.310***	**E+03 3.298**	**E+03 0.343 4.738**	**E+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	2.601	E+01 – 99.99
	generalized	Forces	of	the column	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 N (

N) 3.889E+03 3.633E+03 7.048 5.007E+03 B

– 22.327 Vy (N) 1.588E+03 1.570E+03 1.070 2.266E+03 – 29.938 Vz

(N) 3.497E+04	**3.380E+04**	***3.461 3.325***	**E+04 5.172 MT**	**(N.m) 1.786E-**	**03 1.756**	**E-01 –**
98.983 2.169	E+01	– 99.99	Mfy (N.m) 3.378	E+04	3.204E+04	5.445 3.264
	E+04	3.507 Mfz	(N.m) 5.050E+	02 5.149	E+02 –	1.933 7.659
	E+02 –	34.067 PM	2: 3.0	N (N)	3.889E+03	3.632E
	+03 7.047	5.007E+03 –	22.330 the 1st	bottom	Vy (N) 1.566	E+03 1.554
	E+03 0.785	2.235	E+03 – 29.911	M	3160, N1245	Vz (
	N) 3.476E+	04 3.364E+	04 3.304 3.290	E+04	5.646 MT (	N.m) 1.786E-
03 1.646E-	01 –	98.915 2.167	E+01 –	99.99	Mfy (N.m) 1.861	E+04 1.858
E+04 0.181	1.752E	+04 6.243	Mfz (N.m) 1.863	E+03	1.825E+03	2.075 2.623
E+03 – 28.960	PM3	: 4.5 N	(N) 2.039E	+03 1.910	E+03 6.770	2.641
	E+03 –	22.799 M3162	, N1530 Vy	(N) 1.338	E+03 1.321	E+03 1.255
	1.934E+03	– 30.834	Vz (N) 3.109	E+	04 3.050E+	04 1.931
	2.997E+	04 3.751 MT	(N.m) 1.543	E-03	1.402E-	01 – 98.900
2.573E+01	– 99.99	Mfy (	N.m) 1.441E+03	1.397	E+03 3.154	1.447E+03
– 0.374 Mfz	(N.m) 1.253	E+02 1.295	E+02 –	3.277	1.900E+02	– 34.035
	PM4:	6.0 N (N)	2.039E+03	1.910	E+03 6.767	2.640
	E+03 – 22.780	the 2nd	Vy bottom	(N) 1.282E	+03 1.270E	+03 0.924
	1.859E+03	– 31.030	M3164, N1815	Vz	(N) 3.040	E+04 2.990
	E+04 1.675	2.935E+04	3.594 MT	(N.m) 1.542	E-03 1.049	E-01 –
98.53 2.573	E+01	– 99.99	Mfy (N.m) 4.656	E+04	4.546E+04	2.413 4.436
E+04 4.969 Mfz	(N.m) 2.089	E+03 2.053	E+03 1.759	2.999	E+03 –	30.340 PM
5: 7.5 N (N	) 5.775	E+02 5.441	E+02 6.129	7.773	E+02 – 25.708	M
	3166, N2106	Vy (N) 7.058	E+02 7.068	E+02 –	0.143 1.045	E+03 –
	32.457 Vz	(N) 1.964E	+04 1.965E	+04 –	0.056 1.937	E+04
	1.389 MT	(N.m) 9.165E-	04 6.137	E-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	]) Component

Altitude	Code_Aster	CASTEM	2000 Variation	in %	the SAMCEF software Variation
in %	N (N) 3.889	E+03 3.633	E+03	7.050 –	–,
Vy (N) 1.592	E+03 1.573	E+03 1.229	– –	Vz (N)	3.501E+04

3.382E+04 3.527 – – MT (N.m) 1.787E-03 1.770E-01 – 98.991 –

– Mfy $Z(m)$	(N.m) 8.626E+04	*8.273E+04*	4.267 – –	Mfz (N.m) 2.891	E+03	2.872E+03 0.647
$PM0:0.0$	–	– N (	N) 3.889E+	03 3.633	E+	03 7.048
$M3157$ $N758$	5.007	E+03 – 22.327	, Vy	(N) 1.587		E+03
	1.564E	+03 1.451	2.255E+03	– 29.596		Vz (
	N) 3.497E	+04 3.375E+04	3.620 3.306	E+04 5.773	MT	(N.m)
	1.786E-03	1.718E-	01 – 98.96	2.168	E+	01 –
	99.99 Mfy	(N.m) 3.378	E+04 3.204	E+04 5.452		3.263
$PM1:1.5$	E+04	3.539 Mfz	(N.m) 5.050E	+02 5.147	E+02 –	1.891 7.655
$M3159$ E $N982$	+02 –	34.033 N (	N) 2.039E+	03 1.910	E+03 7.358	2.641E+
	03 – 22.791	, Vy	(N) 1.374	E+03	1.339E+03	2.625
	1.374E+03	– - 29.711	Vz (N) 3.153	E+04 3.071	E+04 2.659	3.017E+
	04 4.493 MT	(N.m) 1.543	E-03 1.540	E	01 – 98.99	2.572
	E+01 – 99.99	Mfy (	N.m) 4.663E+04	4.559E+	04 2.271 4.51	E+04 3.363
$PM2:3.0$	Mfz	(N.m) 1.914	E+03 1.869	E+02 2.396	2.742	E+03 – 30.190
$M3161$ $N1245$	N (N)	2.039E+03	1.909E+03	6.775	2.641E+03	– 22.799
	, Vy (	N) 1.338E+	03 1.298E+	03 3.049	1.902E+	03 –
	29.670 Vz	(N) 3.110E+	04 3.023E+04	2.843 2.969	E+04 4.734	MT (N.m)
	1.543E-	03 1.237E-	01 – 97.75	2.573	E+01 –	99.99
	Mfy (N.m) 1.442	E+03 1.398	E+03 3.095	4.440	E+04 0.110	Mfz (
$PM3:4.5$	N.m) 1.253	E+02 1.298	E+02 – 3.464	1.904	E+02 –	34.174 PM
$M3163$ 4 $N1530$	: 6.0	N (N) 5.778	E+03 5.442	E+02	6.158 7.775	E+02 – 25.689
	the 2nd	bottom	Vy (N)	7.731	E+03 7.402	E+02 4.444
	1.087	E+03 – 28.875	, Vz (N	) 2.054E+	04 2.008E+	04 2.267
	1.977E+04	3.887 MT (	N.m) 9.172E-	04 8.407	E-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 N (N)	5.775E	+02 5.440E	+02 6.153	7.771E	+02 – 25.689	, Vy
$M3165$ (N) $N1815$	7.058E	+02 6.704E	+02 5.279	9.968E	+02 – 29.191	Vz
	(N) 1.964	E+04 1.916E	+04 2.466 1.891	E+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 1.211	E+04 3.566	Mfz	(N.m) 2.431	E+02 2.490

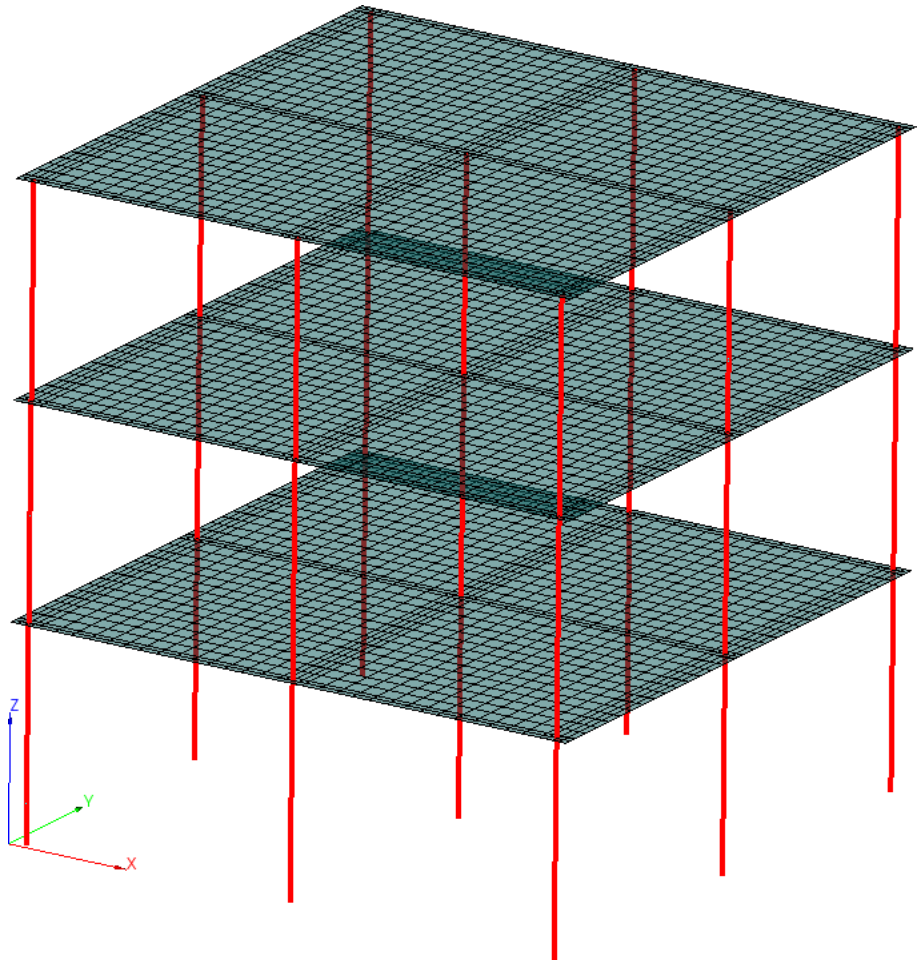
PM5:7.5	E+02	– 2.369 3.816	E+02 –	36.299	Results	of
M3167 the modelization *N2106*		B Remarks	This	modelizatio n		is carried out
		of the command	to test	the option	dal_ saddle-point of	the key
	key	liaison_ elem	affe	_char_me ca	. Characteri stics	
	of the modelization		Figure 5	- has: Mesh	of	the building
	. Appear	5-b:	Detail of	the mesh	around	the columns

5 of bank and exchange. The mesh is

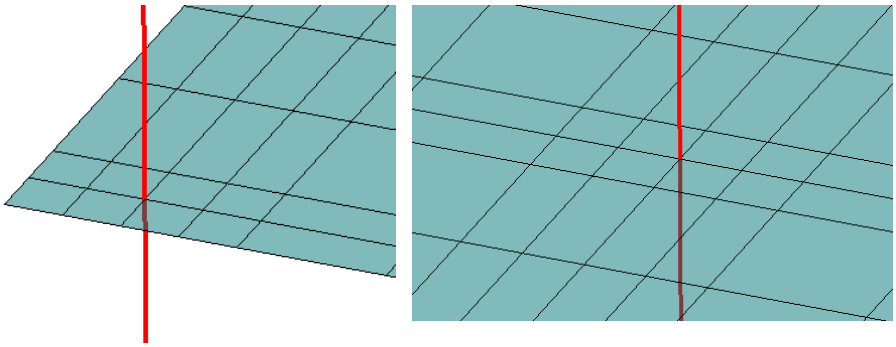
5.1 a little

different from that of modelization A. the distances between centres of THE COLUMNS are respected , BUT a edge of A ½ WIDTH OF

5.2 column is added to slab. Of another



choice 5-a modelization are possible



. Computation 5-b of the eigenfrequencies the frequencies are given in.

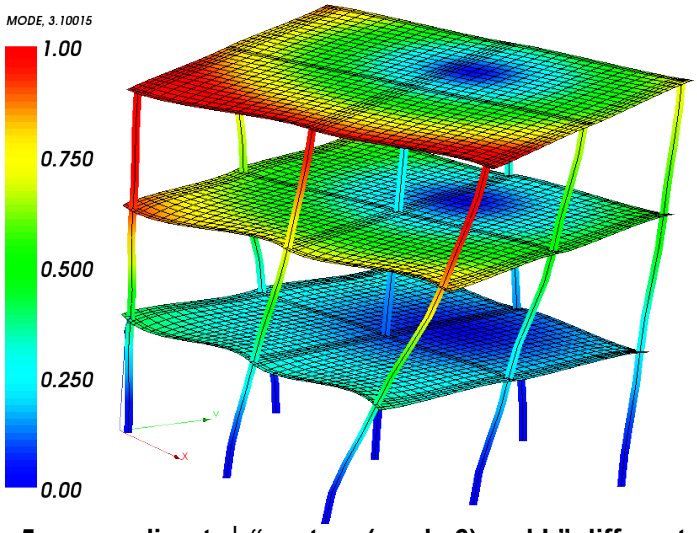
Mode Frequency 1 1.83439E+00 2 2.73610E+00 3 3.10015E+00 4 5.51120E+00 5 8.73582E+00 6 8.94514E+00 7 1.00630E+01 8 1.58920E+01 This modelization is a test of non regression, one thus should not compare the frequencies with

5.3 those obtained by the other

codes. Appear 5-c: 3rd eigen mode Hz

, modelization	HZ
1	. Summary
2	the Comparison
3	with
4	CASTEM 2000
5	: The variations
6	on the eigenfrequencies
7	
8	calculated

with CASTEM 2000 and Aster are lower than. The double mode was separate in two close modes (6 and 7) of which one is a dominating mode



5-c according to L "centers (mode 6) and L" different

6 according to (mode 7); the variation

on the effective modal masses
(en) very high according to for mode 6 and according to mode 7, is not relevant $1,4\ \%$ being given the weak weight of these directions in the modes considered. The variations obtained on computation with y the spectral method, for x displacements remain overall lower than, the variations $\%$ on the reactions to x the fixed support of the columns y B and E are overall lower than (without taking account of the moment of reaction according to Z), and the variations on

the generalized forces remain overall lower than (without taking account of the twisting moment). Strong $8\ \%$ tolerances are allowed for certain computed fields whose values are several weaker orders $11\ \%$ 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 $7\ \%$. 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 structure
. The displacements deferred in the tables are not corrected effects of residual masses which are results also available. The variations on the eigenfrequencies calculated with the SAMCEF software and Aster are lower than. The type of shell element used (deformable or not with the shears) influence result, it goes from there in the same way from the smoothness of the mesh of bottoms. Variations on the eigenfrequencies

going until were observed by initially taking a coarser mesh $3,2\ \%$ for bottoms, consisted by 345 nodes and 516 elements including 108 beam elements right of Timoshenko and 408 elements shell DKT. Modes 6 and 7 represent a mode doubles of which the percentage of effective modal $10\ \%$ mass does not exceed in the direction and the direction. The variations obtained on computation with the spectral method, for displacements in the direction of the excitation remain overall `lower` than. For the reactions to the fixed support of the column, these variations are overall lower $4\ \%$ than. They reach x $2\ \%$ for the column y

, however for the reaction according to the axis and the moment according to the axis, they remain lower than. The reaction of torsion of the columns is not null $10,5\ \%$. The variations in connection with the forces generalized in B the direction of the excitation remain overall $30\ \%$ lower than $80\ \%$. On the other hand, E a coupling different between the directions x from the excitation introduces y important variations on $18\ \%$ the forces into the transverse directions with the excitation. Strong tolerances are allowed for certain computed fields whose values are several weaker orders $26\ \%$ of magnitude. Note: the form of the function describing the spectrum in displacement strongly depends on the eigenfrequencies for which the peaks of displacement
are given. Consequently, a shift of the calculated eigenfrequencies disturbs the seismic response as starter of the data and

does not allow
- an effective comparison of computations, the results of generalized forces are expressed in the local coordinate system f_i of the beams and are corrected static effects.
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