SDLL112 – Seismic analysis of a multimedia beam (spectral response)

Summary

This test relates to the seismic analysis with the spectral method of a beam vertical, embedded at its base and articulated in two points of different altitude. The structure is subjected to an excitation provided in the shape of a spectrum of oscillators in pseudo-acceleration.
Via this problem, L is testedhas modal combination CQC of the operator COMB_SISM_MODAL [U4.84.01], with taking into account or not of the neglected modes.

In addition, the operators are tested CALC_MODES [U4.52.02], NORM_MODE [U4.52.11], MODE_STATIQUE [U4.52.14], DEFI_FONCTION [U4.31.02] and DEFI_NAPPE [U4.31.03].

The validation consists with:

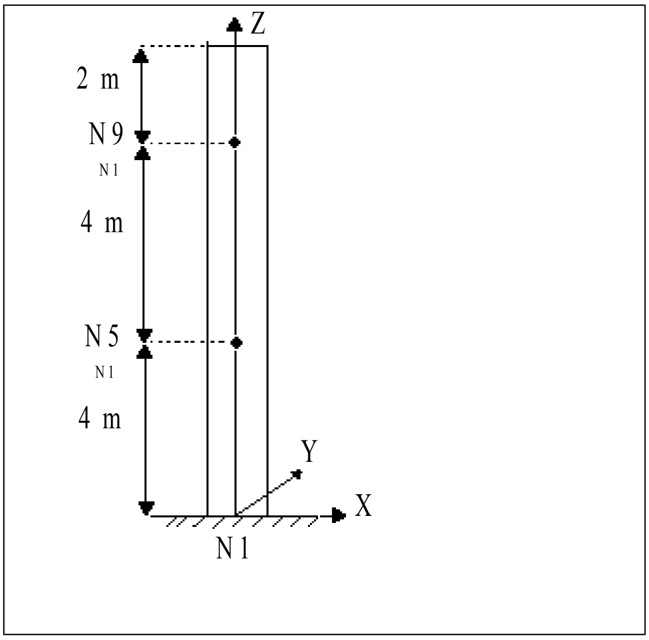
- to compare the results with those obtained using CASTEM 2000 (modeling A (**3D**) : mono-support combination CQC, multi-support excitation identical to the supports combination CQC);
- to find the answer mono-support by the way multi-support, in the case of excitations identical to the supports (modelings A (**3D**) and B (2D), combination CQC);
- to check the not-regression of the answer if there do not exist bench-mark data (different excitations to the supports).

The got results result in agreement with those from CASTEM 2000. In the case of excitations equal to the supports, the answer calculated in multi-support via the option 'CORRELATE' is identical to the answer calculated in mono-support.

1 Problem of reference

1.1 Geometry

The chimney is a vertical beam length $10m$, embedded at its base and articulated in two points of altitude $4m$ and $8m$.



Cross section of the beam:

- Surface: $A=3.4390\,10^{-3}m^2$
- Moments of inertia: $I_y=1.3770.\,10^{-5}m^4$
  $I_z=1.3770.\,10^{-5}m^4$
  $J_x=2.7540\,10^{-5}m^4$

1.2 Material properties

Beam	Young modulus	$E=1.658\,10^{11}\,Pa$
	density	$\rho=1.3404106\,10^4\,kg/m^3$
	Poisson's ratio	$\nu=0,3$

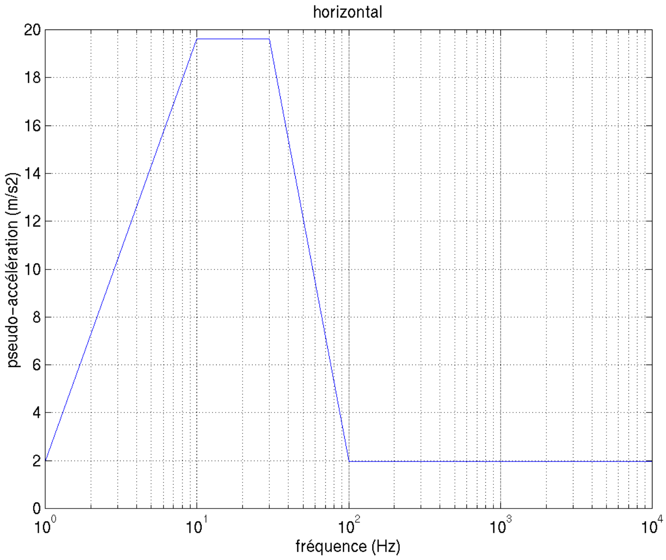
1.3 Boundary conditions and loadings

Modelisation A (3D)
Not $N1$ embedded: $DX=DY=DZ=DRX=DRY=DRZ=0$
Points $N5$ and $N9$ attaches: $DX=DY=0$
Spectra of horizontal oscillators in acceleration applied to the points $N1$, $N5$ and $N9$ in the directions (x) and (x and y).

Modeling B (2D plan XZ)
Problem plan XZ : $DY=DRX=DRZ=0$
Not $N1$ embedded: $DX=DZ=DRY=0$
Points $N5$ and $N9$ attaches: $DX=0$
Spectra of horizontal oscillators in acceleration applied to the points $N1$, $N5$ and $N9$ in the direction (x).

Identical spectra of values for 3 depreciation $0{,}5\%$, 1% and $1{,}5\%$.

Frequency (Hz)	Pseudo-acceleration ($m.s^{-2}$) in x	Pseudo-acceleration ($m.s^{-2}$) in y
1	1,962	1,962
10	19.62	19.62
30	19.62	19.62
100	1,962	1,962
10000	1,962	1,962



For calculation, one uses a reduced damping of 3%, with an interpolation (`LOG LOG`) in frequency and (`FLAX LOG`) in damping.

Case multi-support with different excitations:
not $N1$: excitation $\times 1$
not $N5$: excitation $\times 1.5$
not $N9$: excitation $\times 2$

1.4 Initial conditions

Without object for the spectral analysis

2 Reference solution

2.1 Method of calculating used for the reference solution

Comparison between the results and those obtained using CASTEM 2000 (modeling With (3D): myO-support combination CQC, multi-support excitation identical to the supports combination CQC);

If not, the validation consists with:

- to find the answer mono-support by the way multi-support, in the case of excitations identical to the supports (modelings With (3D) ET B ($2D$), combination CQC);
- to check the not-regression of the answer if there do not exist bench-mark data (modelings A and B, different excitations with the supports).

2.2 Results of reference

Results got using CASTEM 2000: displacements with the nodes $N3$, $N7$ and $N11$ for the following cases:
modeling With (3D)
mono-support, combination CQC
multi-support excitation identical to the supports combination CQC.

2.3 Bibliographical references

Pas de reference published.

3 Modeling A

3.1 Characteristics of modeling

Modeling is three-dimensional. The beam is broken up into 10 elements of modeling `POU_D_E`.

3.2 Characteristics of the grid

Many nodes: 11

Many meshs and types: 10 meshs of the type `SEG2` (`POU_D_E`)
The group of nodes $encastre$ the node contains $N1$ ($dx=dy=dz=drx=dry=drz=0$).
The group of nodes $attache$ contains the nodes $N5$ and $N9$ ($dx=dy=0$).

3.3 Parameters of modeling

Calculation SISM_MO1: Answer in mono-support on the first 10 modes, excitation according to x, without static correction (combination of modal answers CQC)
Calculation SISM_MO2: Answer in mono-support on the first 10 modes, excitation according to x, with static correction (combination of modal answers CQC)

Calculation SISM_MU1: Answer in multi-support on the first 10 modes with identical excitation according to x in all the supports, without static correction and displacements of anchoring (combination of modal answers CQC)
Calculation SISM_MU6: Answer in multi-support on the first 10 modes with identical excitation according to x in all the supports, with static correction and without displacements of anchoring (combination of modal answers CQC)
Calculation SISM_MU2: Answer in multi-support on the first 10 modes with excitations in x and y different and correlated with the supports, with static correction (combination of modal answers CQC), with differential displacements with the supports
Quadratic combination of the directional answers (**`QUAD`**)
Linear combination of the loading cases.

3.4 Sizes tested and results

3.4.1 Excitation mono-support according to X

3.4.1.1 Modal analysis

```
--- VALUES OF THE SPECTRUM ---
 MODE       FREQUENCY     DAMPING    DIR          SPECTRUM
1-2    1.54569D+01       3.00000D-02      X          1.96200D+01
3-4    3.35823D+01       3.00000D-02      X          1.58128D+01
5-6    4.73076D+01       3.00000D-02      X          8.21089D+00
7      5.45850D+01       3.00000D-02      X          6.24517D+00
8      8.80156D+01       3.00000D-02      X          2.50454D+00
9-10   1.01614D+02       3.00000D-02      X          1.96200D+00

TOTAL MASS OF THE STRUCTURE:  4.60967D+02

 MODAL MASS EFFECTIVE CUMULEE:
       DIRECTION: X, OFFICE PLURALITY:  3.09868D+02, IS  67.221%
```

3.4.1.2 Seismic analysis in mono-support

Size: `'depl'`   `NOM_MODE: ('to dir' 'X')`   `NOM_CMP: 'dx'`

Horizontal excitation according to x, Combinaison ‘CQC’ without static correction (calculation SISM_MO1)

Identification	Reference	Tolerance (%)
Displacements according to x	CASTEM 2000	
N3 NODE	1.78952 E -04	0.3
N7 NODE	3.29499 E -04	0.1
N11 NODE	1.09032 E -03	0.1
Absolute acceleration		
N1 NODE		0.0001
N5 NODE		0.0001
N9 NODE		0.0001
Nodal reaction		
N1 NODE		0.0001
N5 NODE		0.0001
N9 NODE		0.0001

Horizontal excitation according to x, Combinaison CQC with static correction (calculation SISM_MO2)

Identification	Reference	Tolerance (%)
Displacements according to x	CASTEM 2000	
N3 NODE	1.78952 E -04	0.3
N7 NODE	3.29499 E -04	0.1
N11 NODE	1.09032 E -03	0.1
Absolute acceleration		
N1 NODE		0.0001
N5 NODE		0.0001
N9 NODE		0.0001
Nodal reaction		
N1 NODE		0.0001
N5 NODE		0.0001
N9 NODE		0.0001

3.4.2 Excitation multi-support according to X

3.4.2.1 Modal analysis

```
--- VALUES OF THE SPECTRUM ---
 MODE       FREQUENCY    DAMPING    DIR   SUPPORT         SPECTRUM
    1-2   1.54569D+01      3.00000D-02         X      N1 N5  N9       1.96200D+01
    3-4   3.35823D+01      3.00000D-02         X     N1 N5  N9       1.58128D+01
    5-6   4.73076D+01     3.00000D-02         X     N1 N5  N9       8.21089D+00
    7     5.45850D+01      3.00000D-02         X     N1 N5  N9       6.24517D+00
    8     8.80156D+01     3.00000D-02         X     N1 N5  N9       2.50454D+00
    9-10  1.01614D+02      3.00000D-02         X     N1 N5  N9       1.96200D+00

TOTAL MASS OF THE STRUCTURE:  4.60967D+02

 MODAL MASS EFFECTIVE CUMULEE:
       DIRECTION: X, OFFICE PLURALITY:  3.09868D+02, IS  67.221%
```

3.4.2.2 Seismic analysis in multi-support (with excitations identical to the supports, without static correction, displacements of anchorings)

Horizontal excitation according to x , Combinaison 'CQC' without static correction (calculation SISM_MU1)

Identification	Reference	Tolerance (%)
Displacements according to x	CASTEM 2000	
N3 NODE	1.78952 E -04	0.3
N7 NODE	3.29499 E -04	0.1
N11 NODE	1.09032 E -03	0.1
Absolute acceleration	AUTRE_ASTER Aster 13.2.2 mono-support §3.4.1.2 SISM_MO1	
N1 NODE	1.96200 E +00	0.0001
N5 NODE	1.96200 E +00	0.0001
N9 NODE	1.96200E+00	0.0001
Nodal reaction	AUTRE_ASTER Aster 13.2.2 mono-support §3.4.1.2 SISM_MO1	
N1 NODE	6.696036 E +02	0.0001
N5 NODE	1.164223 E +03	0.0001
N9 NODE	9.281995 E +02	0.0001

3.4.2.3 Seismic analysis in multi-support (with excitations identical to the supports, with static correction, without displacements of anchorings)

Horizontal excitation according to x , Combinaison CQC with static correction (calculation SISM_MU6)

Identification	Reference	Tolerance (%)
Displacements according to x	CASTEM 2000	
N3 NODE	1.78952 E -04	0.3
N7 NODE	3.29499 E -04	0.1
N11 NODE	1.09032 E -03	0.1

Absolute acceleration	AUTRE_ASTER Aster 13.2.2 mono-support §3.4.1.2	
N1 NODE	1.96200 E +00	0.0001
N5 NODE	1.96200 E +00	0.0001
N9 NODE	1.96200E+00	0.0001
Nodal reaction	AUTRE_ASTER Aster 13.2.2 mono-support §3.4.1.2 SISM_MO1	
N1 NODE	6.716683 E +02	0.2
N5 NODE	1.169727 E +03	0.4
N9 NODE	9.373269 E +02	0.9

3.4.3 Excitation multi-support according to X and there

3.4.3.1 Modal analysis

```
--- VALUES OF THE SPECTRUM ---
 MODE       FREQUENCY    DAMPING    DIR   SUPPORT      SPECTRUM
 1-2          1.54569D+01     3.00000D-02          X Y    N1           1.96200D+01
                                                          N5           2.94300D+01
                                                          N9           3.92400D+01
 3-4          3.35823D+01     3.00000D-02          X Y    N1           1.58128D+01
                                                          N5           2.37192D+01
                                                          N9           3.16256D+01
    5         4.73076D+01     3.00000D-02          X Y    N1           8.21089D+00
                                                          N5           1.23163D+01
                                                          N9           1.64218D+01
    6         4.73076D+01     3.00000D-02          X Y    N1           8.21089D+00
                                                          N5           1.23163D+01
                                                          N9           1.64218D+01
    7         5.45850D+01     3.00000D-02          X Y    N1           6.24517D+00
                                                          N5           9.36775D+00
                                                          N9           1.24903D+01
    8         8.80156D+01     3.00000D-02          X Y    N1           2.50454D+00
                                                          N5           3.75681D+00
                                                          N9           5.00908D+00
    9-10       1.01614D+02     3.00000D-02         X Y    N1           1.96200D+00
                                                          N5           2.94300D+00
                                                          N9           3.92400D+00

TOTAL MASS OF THE STRUCTURE:  4.60967D+02

 MODAL MASS EFFECTIVE CUMULEE:
       DIRECTION: X, OFFICE PLURALITY:  3.09868D+02, IS  67.221%
       DIRECTION: Y, OFFICE PLURALITY:  3.09868D+02, IS  67.221%
```

3.4.3.2 Seismic analysis in multi-support (with correlated different excitations, static correction, displacements of anchorings)

Identical excitations in the two directions x and y
Combination of modes 'CQC'
Combination of the loading cases: 'FLAX'
Combination of directions 'QUAD'
(Calculation SISM_MU2)

Identification	Tolerance (%)
Directional answer according to x	
Displacements according to x	
N3 NODE	0.0001
N5 NODE	0.0001
N7 NODE	0.0001
N9 NODE	0.0001
N11 NODE	
Absolute acceleration	
N1 NODE	0.0001
N5 NODE	0.0001
N9 NODE	0.0001
Nodal reaction	
N1 NODE	0.0001
N5 NODE	0.0001

N9 NODE	0.0001
Directional answer according to y	
Displacements according to y	
N3 NODE	0.0001
N5 NODE	0.0001
N7 NODE	0.0001
N9 NODE	0.0001
N11 NODE	0.0001
Absolute acceleration	
N1 NODE	0.0001
N5 NODE	0.0001
N9 NODE	0.0001
Total answer in displacements	
Component according to x	
N3 NODE	0.0001
N5 NODE	0.0001
N7 NODE	0.0001
N9 NODE	0.0001
N11 NODE	0.0001
Component according to y	
N3 NODE	0.0001
N5 NODE	0.0001
N7 NODE	0.0001
N9 NODE	0.0001
N11 NODE	0.0001

3.5 Remarks

Results in displacements are in concord with those obtained by CASTEM 2000, compared to the combination of modes CQC (error < 0.3%), for the cases mono-support without and with static correction, and multi-support without static correction.
Results in displacements, nodal accelerations and reactions, with excitations equal to the supports, are rigorously identical via two modelings mono-support and multi-support correlated, in the case without static correction. In the case with static correction via the pseudo-mode, a maximum variation of 0.9 % is observed on the nodal reactions.

4 Modeling B

4.1 Characteristics of modeling

Modeling is two-dimensional. The beam is broken up into 10 elements of modeling POU_D_E.

4.2 Characteristics of the grid

Many nodes: 11

Many meshs and types: 10 meshs of the type SEG2 (POU_D_E)
Problem plan: for all the nodes: $dy=0$; $drx=drz=0$
The group of nodes $encastre$ the node contains $N1$ ($dx=dz=dry=0$).
The group of nodes $attache$ contains the nodes $N5$ and $N9$ ($dx=0$).

4.3 Parameters of modeling

Answer in mono-support on the first 5 modes, excitation according to x, without static correction (combination of modal answers CQC)
Answer in mono-support on the first 5 modes, excitation according to x, with static correction (combination of modal answers CQC)

Answer in multi-support on the first 5 modes with identical excitation according to x in all the supports, without static correction and displacements of anchoring (combination of modal answers CQC)
Answer in multi-support on 5 first modes with identical excitation according to x in all the supports, with static correction and without displacements of anchoring (combination of modal answers CQC)
Answer in multi-support on the first 5 modes with excitations in x different and correlated with the supports, with static correction (combination of modal answers CQC)
Linear combination of the loading cases.

4.4 Sizes tested and results

4.4.1 Excitation mono-support according to X

4.4.1.1 Modal analysis

```
--- VALUES OF THE SPECTRUM ---
 MODE      FREQUENCY    DAMPING    DIR        SPECTRUM
    1    1.54569D+01      3.00000D-02      X     1.96200D+01
    2    3.35823D+01      3.00000D-02      X     1.58128D+01
    3    4.73076D+01      3.00000D-02      X     8.21089D+00
    4    8.80156D+01      3.00000D-02      X     2.50454D+00
    5    1.01614D+02      3.00000D-02      X     1.96200D+00

TOTAL MASS OF THE STRUCTURE:  4.60967D+02

 MODAL MASS EFFECTIVE CUMULEE:
       DIRECTION: X, OFFICE PLURALITY:  3.09868D+02, IS  67.221%
```

4.4.1.2 Seismic analysis in mono-support

```
NOM_CHAMP:'depl'            NOEUD_CMP: ('to dir' 'X')      NOM_CMP: 'dx'
NOM_CHAMP:'acce_absolu'     NOEUD_CMP: ('to dir' 'X')      NOM_CMP: 'dx'
NOM_CHAMP:'reac_noda'       NOEUD_CMP: ('to dir' 'X')      NOM_CMP: 'dx'
```

Horizontal excitation according to x , Combinaison 'CQC' without static correction (calculation SISM_MO1)

Identification	Tolerance (%)
Displacements according to x	
N3 NODE	0.0001
N7 NODE	0.0001
N11 NODE	0.0001
Absolute acceleration	
N1 NODE	0.0001
N5 NODE	0.0001
N9 NODE	0.0001
Nodal reaction	
N1 NODE	0.0001
N5 NODE	0.0001
N9 NODE	0.0001

Horizontal excitation according to x , Combinaison CQC with static correction (calculation SISM_MO2)

Identification	Tolerance (%)
Displacements according to x	
N3 NODE	0.0001
N7 NODE	0.0001
N11 NODE	0.0001
Absolute acceleration	
N1 NODE	0.0001
N5 NODE	0.0001
N9 NODE	0.0001
Nodal reaction	
N1 NODE	0.0001
N5 NODE	0.0001
N9 NODE	0.0001

4.4.2 Excitation multi-support according to X

4.4.2.1 Modal analysis

```
--- VALUES OF THE SPECTRUM ---
 MODE      FREQUENCY   DAMPING   DIR   SUPPORT         SPECTRUM
    1        1.54569D+01     3.00000D-02      X      N1 N5 N9         1.96200D+01
    2        3.35823D+01     3.00000D-02      X      N1 N5 N9         1.58128D+01
    3        4.73076D+01     3.00000D-02      X      N1 N5 N9         8.21089D+00
    4        8.80156D+01     3.00000D-02      X      N1 N5 N9         2.50454D+00
    5        1.01614D+02     3.00000D-02      X      N1 N5 N9         1.96200D+00

TOTAL MASS OF THE STRUCTURE:  4.60967D+02

 MODAL MASS EFFECTIVE CUMULEE:
```

4.4.2.2 Seismic analysis in multi-support (with excitations identical to the supports, without static correction, displacements of anchorings)

```
NOM_CHAMP:'depl'          NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
NOM_CHAMP:'acce_absolu'   NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
NOM_CHAMP:'reac_noda'     NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
```

Combination 'CQC' without static correction (calculation SISM_MU1)

Identification	AUTRE_ASTER Aster 13.2.2 mono-support §4.4.1.2 SISM_MO1	Tolerance (%)
Displacements according to x		
N3 NODE	0.000178493287046	0.0001
N7 NODE	0.00032927087105	0.0001
N11 NODE	0.00108971744115	0.0001
Absolute acceleration		
N1 NODE	1,962	0.0001
N5 NODE	1,962	0.0001
N9 NODE	1,962	0.0001
Nodal reaction		
N1 NODE	669.603610534	0.0001
N5 NODE	1164.22268299	0.0001
N9 NODE	928.199473667	0.0001

4.4.2.3 Seismic analysis in multi-support (with excitations identical to the supports, with static correction, without displacements of anchorings)

```
NOM_CHAMP:'depl'            NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
NOM_CHAMP:'acce_absolu'     NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
NOM_CHAMP:'reac_noda'       NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
```

Combination 'CQC' with static correction (calculation SISM_MU6)

Identification	AUTRE_ASTER Aster 13.2.2 mono-support §4.4.1.2 SISM_MO2	Tolerance (%)
Displacements according to x		
N3 NODE	0.000178493681539	0.0001
N7 NODE	0.000329270911406	0.0001
N11 NODE	0.00108971827966	0.0001
Absolute acceleration		
N1 NODE	1,962	0.0001
N5 NODE	1,962	0.0001
N9 NODE	1,962	0.0001
Nodal reaction		
N1 NODE	671.668298435	0.2
N5 NODE	1169.72688401	0.4
N9 NODE	937.326875436	0.9

4.4.2.4 Seismic analysis in multi-support (with correlated different excitations, static correction, displacements of anchorings)

```
NOM_CHAMP: 'depl'           NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
NOM_CHAMP: 'depl'           NOEUD_CMP: ('to dir' 'there')     NOM_CMP: 'Dy'
NOM_CHAMP: 'acce_absolu'    NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
NOM_CHAMP: 'reac_noda'      NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'dx'
NOM_CHAMP: 'depl'           NOEUD_CMP: ('to dir' 'X')     NOM_CMP: 'combi' 'quad'
NOM_CHAMP: 'depl'           NOEUD_CMP: ('to dir' 'there')     NOM_CMP:     'combi'
'quad'
```

Combination of modes 'CQC'
Combination of the loading cases: 'FLAX'
(calculation SISM_MU2)

Identification	Tolerance (%)
Answer according to x	
Displacements according to x	
N3 NODE	0.0001
N5 NODE	0.0001
N7 NODE	0.0001
N9 NODE	0.0001
N11 NODE	0.0001
Absolute acceleration	
N1 NODE	0.0001
N5 NODE	0.0001
N9 NODE	0.0001
Nodal reaction	
N1 NODE	0.0001
N5 NODE	0.0001
N9 NODE	0.0001

4.5 Remarks

Results in displacements are in concord with those obtained by CASTEM 2000, compared to the combination of modes CQC (error < 0.3%), for the cases mono-support without and with static correction, and multi-support without static correction.
Results in displacements, nodal accelerations and reactions, with excitations equal to the supports, are rigorously identical via two modelings mono-support and multi-support correlated, in the case without static correction. In the case with static correction via the pseudo-mode, a maximum variation of 0.9 % is observed on the nodal reactions.

5 Summary of the results

For each modeling A (3D) and B (2D plan):
- Lbe results in displacements are in concord with those obtained by CASTEM 2000, compared to the combination of modes CQC (error < 0.3%), for the cases mono-support without and with static correction, and multi-support without static correction.
- Lbe results in displacements, nodal accelerations and reactions, with excitations equal to the supports, are rigorously identical via two modelings mono-support and multi-support correlated, in the case without static correction. In the case with static correction via the pseudo-mode, a maximum variation of 0.9 % is observed on the nodal reactions, between the configurations mono-support and multi-support.