SDLL149 – Calcul seismic of piping BM3 (test NRC)

Summary:
This test mainly makes it possible to validate the implementation of the method GUPTA (correlation between periodicals part and rigid of a modal answer) on a seismic calculation by spectral method applied to part of piping (COMB_SISM_MODAL).

Other methods are also evaluated on the same configuration:

- SRSS,
- CQC,
- CQC with pseudo-mode.

This test was proposed by NRC to validate the seismic dimensioning of nuclear installations.

1 Problem of reference

1.1 Problems

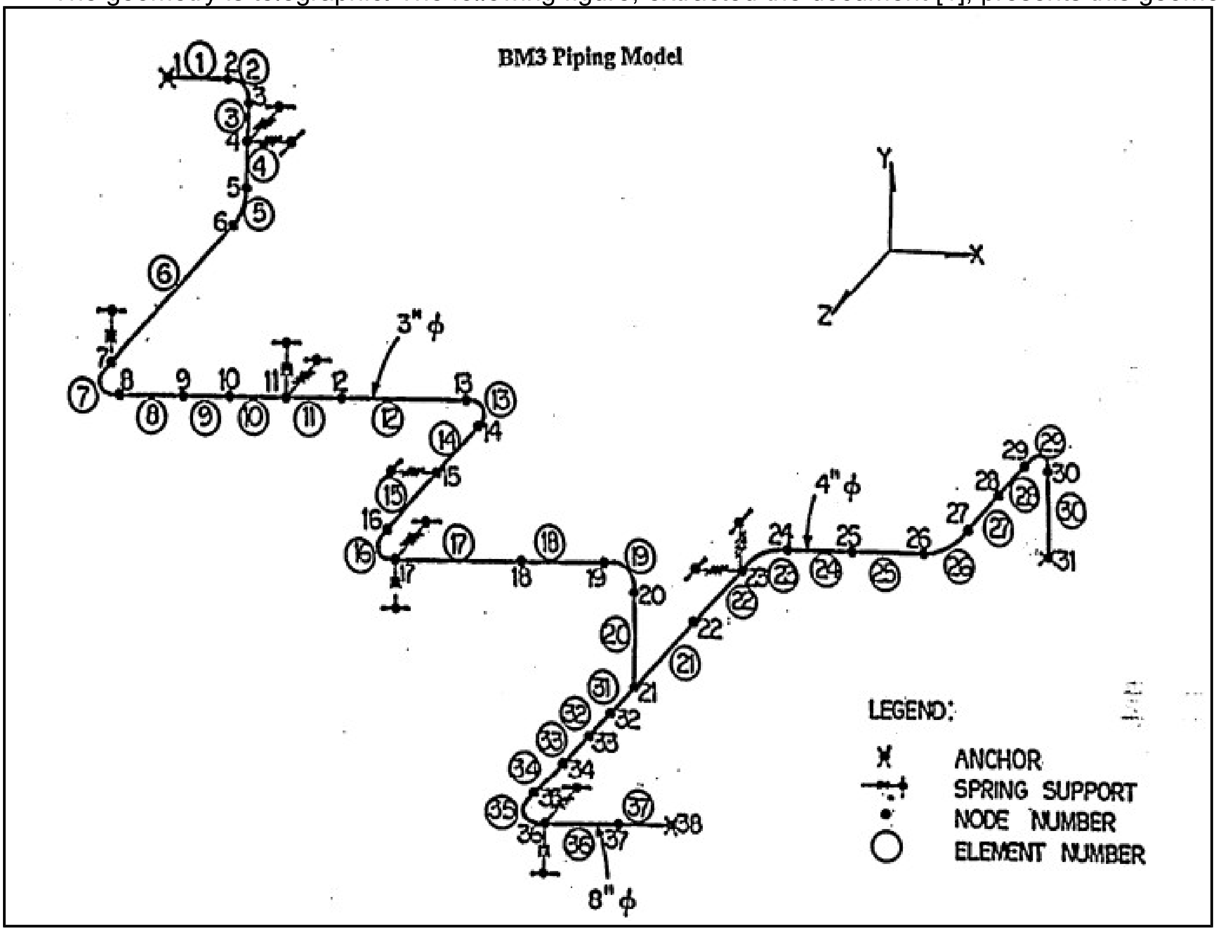
This test consists in carrying out a spectral analysis of the network of drains BM3 used in a nuclear power plant. It makes it possible to validate the various methods of combination used, in other the method of Gupta. To carry out this validation, the results of an equivalent modeling carried out with ANSYS are extracted from the two following documents:

[1] Revaluation of Modal Regulatory Guidance one Answer Combination Methods for Seismic Answer Spectrum Analysis, NUREG/CR-6645, BNL-NUREG-52576, 1999.

[2] ANSYS Mechanical APDL Technology Demonstration Guides, 2010, Chapter 12: Dynamic Simulation of has Nuclear Piping System Using RSA Methods.

1.2 Geometry

The geometry is telegraphic. The following figure, extracted the document [1], presents this geometry:



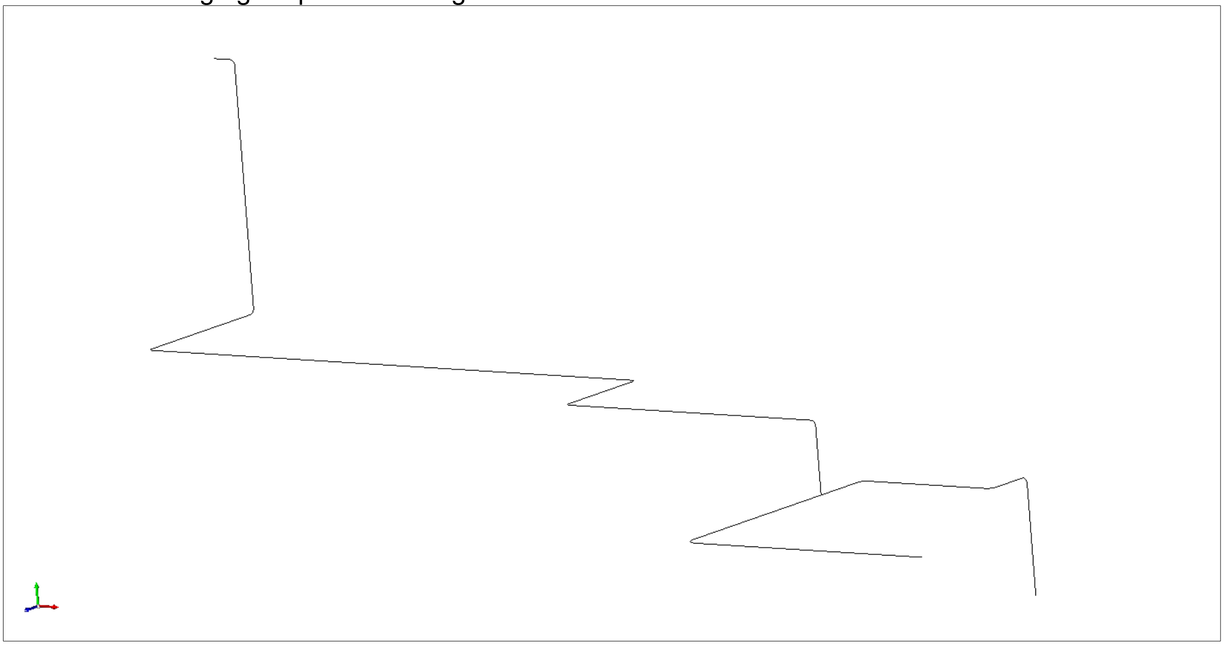
In order to compare itself correctly with the American studies [1] and [2], the selected units are the imperial units.

The structure is made up of three parts with different sections. The following table shows the characteristics of the sections:

	Ray (inch)	Thickness (inch)
section 1	1,75	0.216
section 2	2,25	0.237
section 3	4,31	0.322

1.3 Grid

The grid of the structure linear and is composed of 37 elements SEG2 for 38 nodes.
The following figure presents the grid under SALOME-MECA-2012.1:



The following table presents the coordinates of the nodes of the grid:

	Coordinates (inch)		
Nodes	X	Y	Z
1	0	0	0
2	15	0	0
3	19.5	-4.5	0
4	19.5	-180	0
5	19.5	-199.5	0
6	19.5	-204	4.5
7	19.5	-204	139.5
8	24	-204	144
9	96	-204	144
10	254	-204	144
11	333	-204	144
12	411	-204	144
13	483	-204	144
14	487.5	-204	148.5
15	487.5	-204	192

	Coordinates (inch)		
16	487.5	-204	235.5
17	492	-204	240
18	575	-204	240
19	723	-204	240
20	727.5	-208.5	240
21	727.5	-264	240
22	727.5	-264	205
23	727.5	-264	190
24	733.5	-264	184
25	753.5	-264	184
26	845.5	-264	184
27	851.5	-264	178
28	851.5	-264	160
29	851.5	-264	142
30	851.5	-270	136
31	851.5	-360	136
32	727.5	-264	255
33	727.5	-264	270
34	727.5	-264	306
35	727.5	-264	414
36	739.5	-264	426
37	847.5	-264	426
38	955.5	-264	426

The supports of this structure are modelled by stiffnesses. To be able to recover the nodal reactions to the supports, an additional node “doubled bloom”, is created for each support. It is shifted of $1{,}\mathrm{E}\text{-}3\,inch$ (tolerance of Code_Aster) along the axis X compared to the something to lean on. All its degrees of freedom are blocked and an element SEG2 is created between the node of the support and the “doubled bloom”. It is on this element that the values of stiffness of the supports will be applied. Thus, the nodal reactions will be raised with nodes “doubled blooms”.

1.4 Materials

The properties structural materials are the following ones:

$E=2{,}9\mathrm{E}{+}7\ pound/inch^2$

$\nu=0{,}3$

The densities of the structure are the following ones:

	Ray (inch)	Thickness (inch)	Section (inch ²)	Linear density (pound/inch)	Density (pound/inch3)
section 1	1,7500	0.216	2,2273	2,3240E-003	**1,0434E-003**
section 2	2,2500	0.237	3,1724	3,5145E-003	**1,1078E-003**
section 3	4,3125	0.322	8,3950	1,0836E-002	**1,2908E-003**

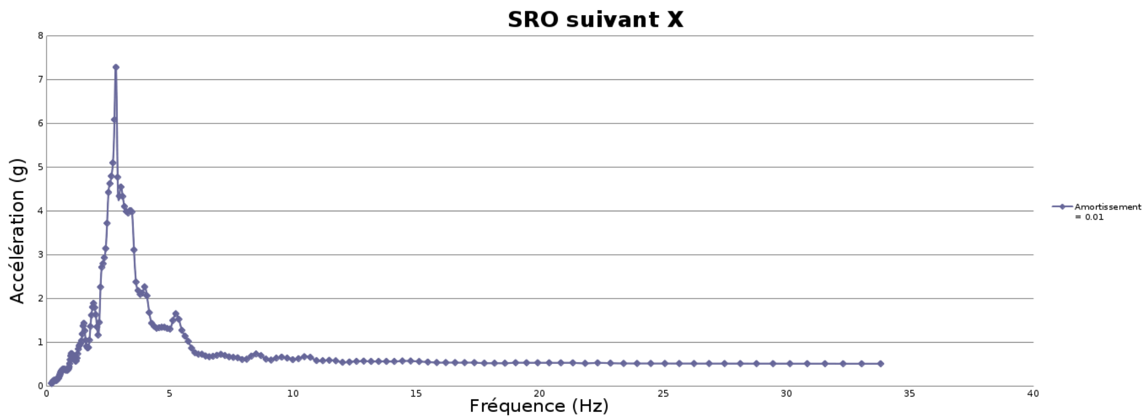
Note: In the document [2] of 2010, the density of section 3 is of $1.253\mathrm{E}-3\ pound/inch^3$. In order to keep coherence in all modelings, it is the value of the document [1] of 1999 which is used.

1.5 Boundary conditions and loadings

The boundary conditions correspond to the supports of the structure. They are modelled by stiffnesses with the corresponding nodes of the grid. The stiffnesses are the following ones:

Nodes	Stiffness UX (pound/inch)	Stiffness UY (pound/inch)	Stiffness UZ (pound/inch)	Stiffness RX (pound/inch)	Stiffness RY (pound/inch)	Stiffness RZ (pound/inch)
1	1,00E+011	1,00E+011	1,00E+011	1,00E+020	1,00E+020	1,00E+020
4	1,00E+008	0,00E+000	1,00E+008	0,00E+000	0,00E+000	0,00E+000
7	0,00E+000	1,00E+008	0,00E+000	0,00E+000	0,00E+000	0,00E+000
11	0,00E+000	1,00E+008	1,00E+005	0,00E+000	0,00E+000	0,00E+000
15	1,00E+005	0,00E+000	0,00E+000	0,00E+000	0,00E+000	0,00E+000
17	0,00E+000	1,00E+008	1,00E+005	0,00E+000	0,00E+000	0,00E+000
23	1,00E+005	1,00E+008	0,00E+000	0,00E+000	0,00E+000	0,00E+000
31	1,00E+011	1,00E+011	1,00E+011	1,00E+020	1,00E+020	1,00E+020
36	0,00E+000	1,00E+008	1,00E+005	0,00E+000	0,00E+000	0,0E+0
38	1,00E+011	1,00E+011	1,00E+011	1,00E+020	1,00E+020	1,00E+020

The loading of the spectral analysis corresponds to a Spectrum of Answer of Oscillator applied in the direction X. The spectrum is presented in the following graph:



1.6 Modeling

Element BEAM (2 modelings):

- modeling POU_D_T for the cross-sections and for the curved sections
- modeling DIS_TR for the supports

2 Modeling A

2.1 Characteristics of modeling

This modeling seeks to approach the document [2] of 2010. For that, the matrix of calculated mass is full.

The modal analysis raises the first 14 modes and five spectral analyses are carried out:
1) Combination SRSS
2) Combination CQC
3) Combination CQC with static correction
4) Combination of the Gupta type with $f1=2{,}80\,Hz$ and $f2=11{,}90\,Hz$ with static correction
5) Combination of the Gupta type with $f1=2{,}80\,Hz$ and $f2=6\mathrm{Hz}$ with static correction

2.2 Sizes tested and results

The sizes tested are the Eigen frequencies of the first 14 modes and the reactions to the supports of the structure. The tests use as references the values resulting from ANSYS. They are doubled tests of not-regression with a tolerance of $1{,}E\text{-}6$.

Mode clean	Reference Frequencies (Hz)	Tolerance Code_Aster (%)
1	2,91	1
2	4,44	2
3	4,86	1
4	5,02	1
5	6,95	1
6	7,58	2
7	7,82	1
8	10,94	2
9	11,65	3
10	11,78	2
11	12,8	2
12	14,32	3
13	15,17	8
14	15,79	6

Nodes	Efforts	Reference calculation 1 (F: lbs, M: lbs-inch)	Tolerance Code_Aster calculation 1 (%)	Reference calculation 2 (F: lbs, M: lbs-inch)	Tolerance Code_Aster calculation 2 (%)	Reference calculation 3 (F: lbs, M: lbs-inch)	Tolerance Code_Aster calculation 3 (%)
1	FX	30.69	13	30,81	13	43,85	3
1	FY	15,34	10	12,59	9	15,21	8
1	FZ	49,04	9	24,91	5	24,91	5
1	MX	1515,03	6	764,29	7	766,72	7
1	MY	1219,62	6	932,32	0,15	934,03	1
1	MZ	1100,66	12	1096,58	12	1108,78	11
4	FX	45,19	5	45,02	5	77,36	3
4	FZ	82,15	2	55,61	1	56,12	1
7	FY	27,87	2	15,78	11	15,99	9
11	FY	21,54	20	19,57	20	19,59	20
11	FZ	42,91	4	42,35	2	43,43	3
15	FX	368,83	2	388,99	3	389,64	3
17	FY	44,28	0,3	45,83	2	45,95	2
17	FZ	53,12	2	55,06	1	55,31	0,1
36	FY	162,84	3	169,14	1	171,57	3
36	FZ	80,96	8	81,34	6	90,69	10
38	FX	116,92	4	135,99	5	566,65	12
38	FY	52,46	2	54,26	1	54,29	1
38	FZ	39,12	7	44,55	6	50,45	5,5
38	MX	2543,44	1	2606,69	3	2606,69	3
38	MY	2533,41	65	2894,27	5	3142,75	4,5
38	MZ	3650,45	2	3763,01	1	3764,97	1
23	FX	177,23	5	193,92	5	245,05	4
23	FY	145,37	4	151,53	1	151,99	1
31	FX	9,41	2	11,09	2	54,42	6
31	FY	22,08	6	24,77	5	27,73	4
31	FZ	31,36	8	32,11	7	32,26	7
31	MX	1971,58	16	2068	14	2072,03	14
31	MY	267,63	23	304,18	23	567,6	28
31	MZ	603,06	6	706,86	3	1912,58	4

Nodes	Efforts	Reference calculation 4 (F: lbs, M: lbs-inch)	Tolerance calculation 4 (%)	Reference calculation 5 (F: lbs, M: lbs-inch)	Tolerance calculation 5 (%)
1	FX	54,42	1	52,05	1
1	FY	3,43	8	2,73	16
1	FZ	6,61	4	4,93	25
1	MX	190,18	13	135,39	11
1	MY	858,44	2	877,81	4
1	MZ	966,87	3	864,96	2
4	FX	105,14	1	114,06	1
4	FZ	42,48	6	34,9	6
7	FY	8,77	21	6,77	39
11	FY	16,71	33	12,44	37
11	FZ	49,19	2	61,99	3
15	FX	547,38	2	641,84	1
17	FY	35,92	1	26,39	2
17	FZ	56,34	2	46,86	3
36	FY	81,01	5	61,16	21
36	FZ	60,87	3	42,38	20
38	FX	750,45	10	739,29	10
38	FY	46,02	2	42,92	1
38	FZ	45,53	8	41,67	6,5
38	MX	914,22	9	369,64	3
38	MY	3191,39	7	2909,01	6
38	MZ	3248,59	2	3036,62	1
23	FX	347,2	4	304,8	5
23	FY	49,61	11	16,75	12
31	FX	63,82	3	61,95	3
31	FY	16,89	4	13,34	6
31	FZ	19,53	11	12,96	4,2
31	MX	1235,04	19	695,41	19
31	MY	818,08	31	757,2	32
31	MZ	2460,9	2	2319,49	3

3 Modeling B

3.1 Characteristics of modeling

This modeling to seek to approach the document [1] of 1999. For that, the matrix of calculated mass is diagonalisée.

The modal analysis raises the first 14 modes and three spectral analyses are carried out:

6) 1. Combination SRSS
7) 2. Combination CQC
8) 3. Combination of the Gupta type with $f1=2,80\ Hz$ and $f2=11,90\ Hz$

3.2 Sizes tested and results

The sizes tested are the Eigen frequencies of the first 14 modes the reactions to the supports of the structure. The tests use as references the values resulting from ANSYS. They are doubled tests of not-regression with a tolerance of $1,E\text{-}6$.

Mode clean	Reference Frequencies (Hz)	Tolerance Code_Aster (%)
1	2,91	0,12
2	4,39	0,12
3	5,52	0,1
4	5,7	0,1
5	6,98	0,23
6	7,34	0,1
7	7,88	0,1
8	10,3	0,1
9	11,06	0,1
10	11,23	0,1
11	11,5	0,2
12	12,43	0,21
13	13,88	0,3
14	16,12	0,55

Nodes	Efforts	Reference calculation 1 (F: lbs, M: lbs-inch)	Tolerance calculation 1 (%)	Reference calculation 2 (F: lbs, M: lbs-inch)	Tolerance calculation 2 (%)	Reference calculation 3 (F: lbs, M: lbs-inch)	Tolerance calculation 3 (%)
1	FX	3,13	2	3,13	1	3,25	2
1	FY	5,44	2	5,05	2,2	3,4	7
1	FZ	7,48	1	6,76	1	2,47	7
1	MX	275,37	1	246,84	1	64,41	15
1	MY	690,81	1	682,86	1	690,81	0.3
1	MZ	209,33	2	202,85	1,1	185,59	3
4	FX	24,27	1,2	23,98	2	23,98	0.34
4	FZ	75,18	2	67,72	2	25,43	6
7	FY	15,53	4	15,26	5	14,42	5
11	FY	19,61	1	19,08	1	15,63	2
11	FZ	79,99	1	77,2	2	74,41	2
15	FX	437,58	2	437,85	1	550,84	1
17	FY	48,82	1	48,05	1	39,11	1
17	FZ	79,11	2	79,73	2	62,91	1
36	FY	90,5	2	90,03	2	59,08	2
36	FZ	78,39	3	79,08	3	75,67	4
38	FX	119,47	4,3	121,91	2,3	163,36	4
38	FY	52,78	1	52,78	1	48,38	2
38	FZ	38,38	4	40,09	4,2	56,3	4,3
38	MX	1404,67	2	1397,54	2	762,94	4
38	MY	2588,19	4,3	2699,51	4,4	3701,39	4,3
38	MZ	3710,18	1	3710,18	1	3429,58	1
23	FX	214,93	2	219,71	2	238,81	3
23	FY	105,28	3	104,16	3	40,04	6
31	FX	10,13	4	10,2	3,3	9,86	3
31	FY	24,83	2	24,97	1,1	17,72	1
31	FZ	31,62	4	30,69	3,4	23,56	2,5
31	MX	2436,08	5	2358,92	4,8	1763,68	3,6
31	MY	282,8	4,1	287,99	4,2	306,15	3
31	MZ	796,48	4,3	802,56	4,2	772,16	3

4 Modeling C

4.1 Characteristics of modeling

This modeling validates the use of the dynamic under-structuring for spectral seismic calculation. It compares a calculation by dynamic under-structuring with a "direct" calculation (without dynamic under-structuring).

4.2 Sizes tested and results

4.2.1 Modal calculation: frequencies of the line of piping

One tests the first 14 Eigen frequencies of piping and one compares the results of calculation by dynamic under-structuring with those of the reference [1].

Mode clean	Reference Frequencies (Hz)	Tolerance Code_Aster (%)
1	2,91	1
2	4,44	2
3	4,86	1
4	5,02	1
5	6,95	1
6	7,58	2
7	7,82	1
8	10,94	1
9	11,65	2
10	11,78	2
11	12.80	2
12	14,32	2
13	15,17	6
14	15,79	4

4.2.2 Seismic answer by spectral calculation

One compares displacements according to the direction DX with the nodes $N10$ coordinates $(254.0, -204.0, 144.0)$, $N20$ coordinates $(727.5, -208.5, 240.0)$ and $N30$ coordinates $(851.5, -270.0, 136.0)$ the calculation of spectral seismic answer with the base resulting from the under-structuring with those calculated with the base resulting from "direct" calculation.

Node	Displacement max in DX ("direct" calculation)	Tolerance (%)
$N10$	0.274320 inches	0.2
$N20$	0.179173 inches	0.2
$N30$	0.00825 inches	5.0

One creates the same table for absolute accelerations:

Node	Absolute acceleration max in DX ("direct" calculation)	Tolerance (%)
$N10$	227.616 inches/s ²	0.2
$N20$	285.906 inches/s ²	3.0
$N30$	177.284 inches/s ²	4.0

5 Summary of the results

The got results are overall satisfactory. That it is with a matrix of complete mass or a matrix of diagonal mass, the frequencies of the publications are found.

The results on the nodal reactions resulting from calculation by spectral seismic method are for the majority close relations of the results of reference to less than 5%. However, it is noticed that on some something to lean on the variations on the nodal reactions enters *Code_Aster* and ANSYS rise with more than 30% (modeling A). They are explained by differences on the modal deformations calculated by the two software (up to 2% on modeling B), just as on the reactions to the supports of the modes (up to 5% of variation in modeling B). One can make go up these differences with implementations distinct on the finite elements from beam enter the two codes. In particular for modeling A, ANSYS employs an interpolation “finite elements” for the elements of beam whereas *Code_Aster* use an “exact” integration [R3.08.01 – “exact” elements of beam].

It is noted nevertheless that they remain largely in on this side differences resulting from the choice of the method or effect of “missing mass” (effect of the modes high frequency).

With regard to the method known as of Gupta, it appears validated well by this external reference.

Modeling a.c. for interest to validate employment for a spectral seismic answer of a modal base resulting from a calculation by dynamic under-structuring.