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Experimental modal and static tests on a rack by Bassocontinuo - Revolution X

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Summary

Present document resumes the results obtained during the modal and static tests performed by Vicoter on the “Revolution X” rack manufactured by Bassocontinuo.

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1. Introduction

Vicoter tested the "Revolution X" rack manufactured by Bassocontinuo (Figure 1). Following tests are performed:

1. Modal analysis.
2. Static test under compression.

The purpose of the tests is twofold. From a dynamic point of view, Vicoter characterizes the behaviour of the rack up to the maximum observable frequency by measuring the resonance frequencies, the damping and the modal shapes. Tests are performed both in unloaded configuration and loading each shelf with 30 kg.
Form the static point of view, each shelf of the rack is loaded progressively to a maximum load of 60 kg and the load vs. deflection curves are recorded.

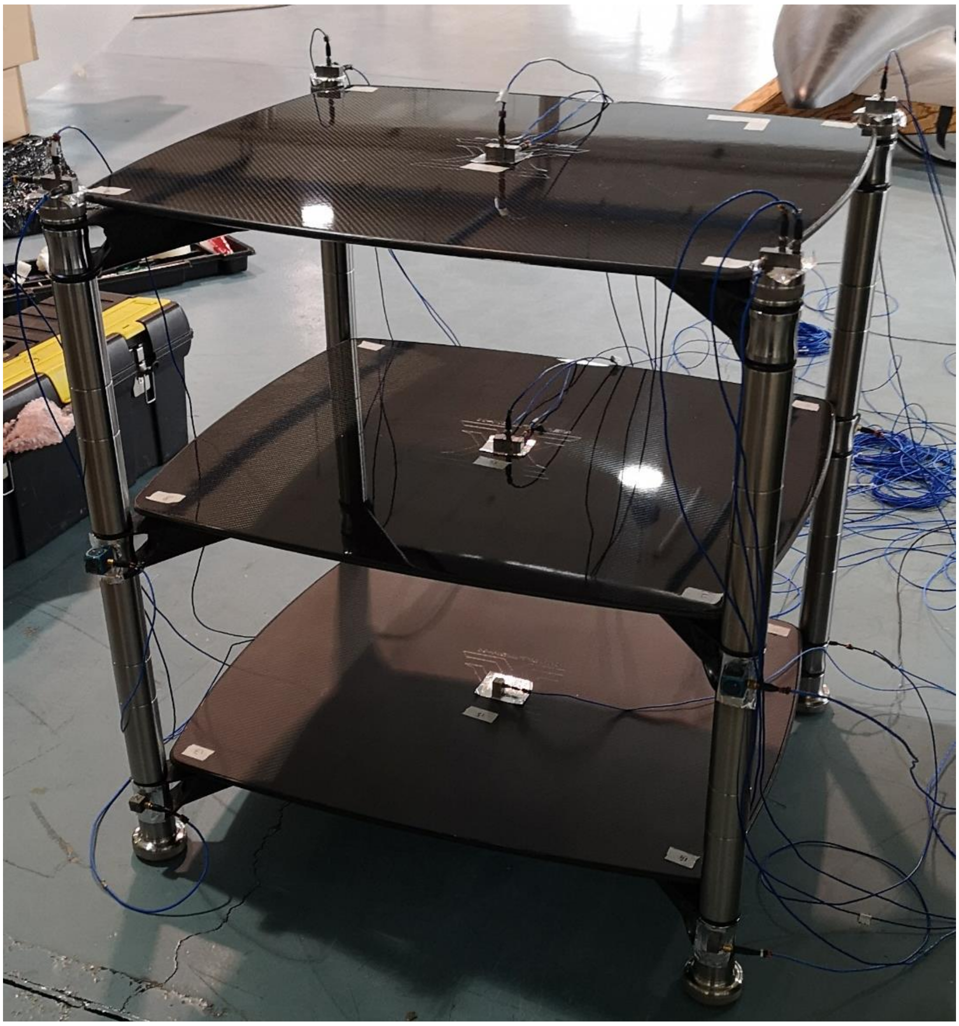


Figure 1. "Revolution X" rack during tests.

2. Modal analysis

2.1. Experimental setup

Modal tests are performed with the following instrumentation:

- 1 SCADAS 316 front-end for signal conditioning and acquisition.
- 18 PCB 333B32 uniaxial accelerometers, bandwidth from 0.5 Hz to 3 kHz (±5%) and full-scale equal to ±50 g peak.
- 5 PCB 356B08 triaxial accelerometers, bandwidth from 0.5 Hz to 5 kHz (±5%) and full-scale equal to ±50 g peak.
- 1 PCB M356A22 triaxial accelerometer, bandwidth from 0.5 Hz to 4 kHz (±5%) and full-scale equal to ±50 g peak.
- 2 PCB 356A02 triaxial accelerometers, bandwidth from 1 Hz to 5 kHz (±5%) and full- scale equal to ±500 g peak.
- 1 PCB 356A45 triaxial accelerometer, bandwidth from 0.7 Hz to 7 kHz (±5%) and full-scale equal to ±50 g peak.
- 1 instrumented hammer with a PCB 086B03 load cell, to excite the structure. The hammer is equipped with a Teflon tip able to excite the band up to 2048 Hz.
- Software LMS-TestLab, release 17, for data-processing.

The rack is instrumented in 15 points. On each point, a tri-axial acceleration measurement is carried out. Corresponding wireframe is shown in Figure 2.

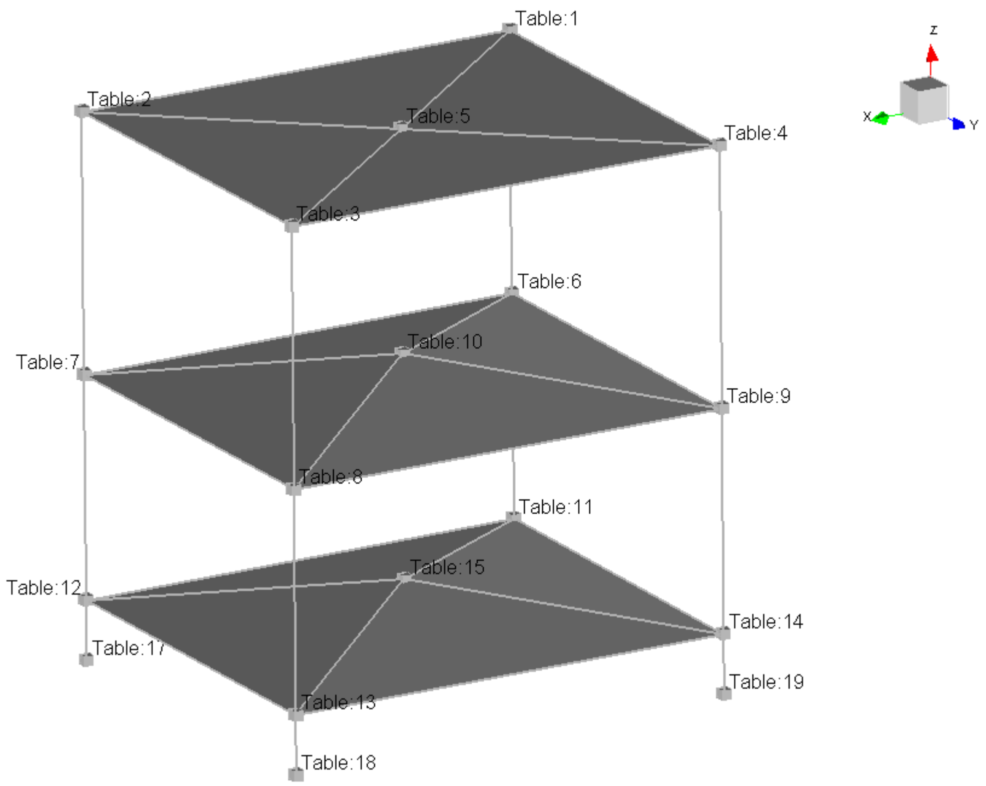


Figure 2. "Revolution X" wireframe for modal tests.

Rack during the tests, as well as some particulars of sensors installation, is presented in Figure 3 and in Figure 4.

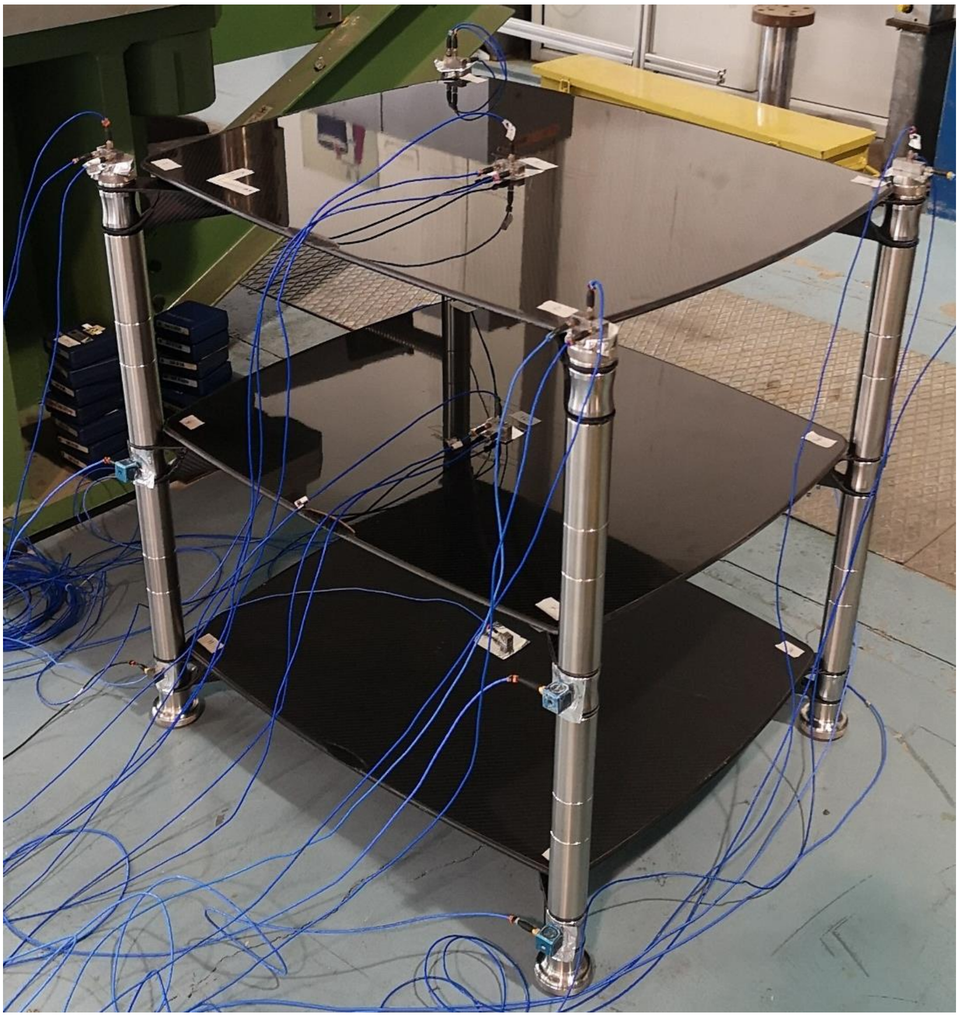


Figure 3. "Revolution X" during modal tests.

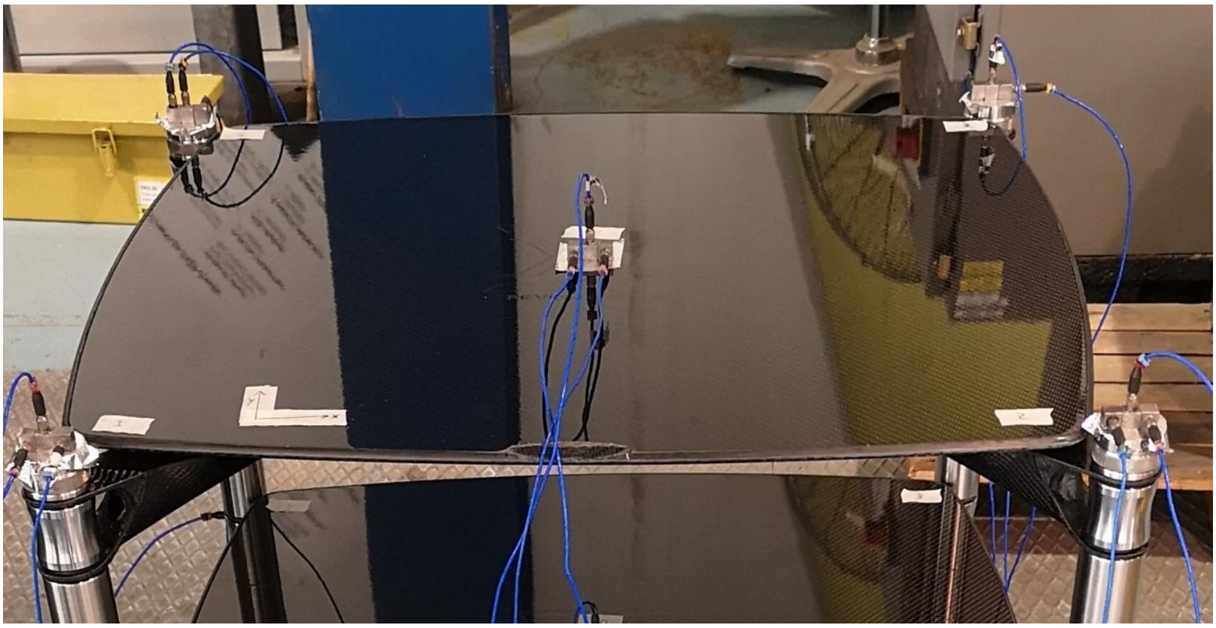


Figure 4. "Revolution X" – Sensor installation on the top shelf during modal tests.

Following dynamic tests are performed:

1. Tests on unloaded rack.
2. Tests on rack loaded up to 90 kg, 30 kg on each shelf.

Both tests were performed using a MIMO (Multi Input Multi Output) technique in which the input force was provided by means of an instrumented hammer. The impacts were made in three different points, exciting all three orthogonal directions in order to avoid possible modal nodes. A sampling frequency of 4096 Hz and an observation time of 8 seconds were used to obtain a frequency resolution of 0.125 Hz. The modes were identified starting from the FRFs (Frequency Response Functions) acquired using the Polymax algorithm.

2.2. Results

Modal tests on unloaded rack

These tests are performed on the rack without any additional weight, as shown in Figure 5.

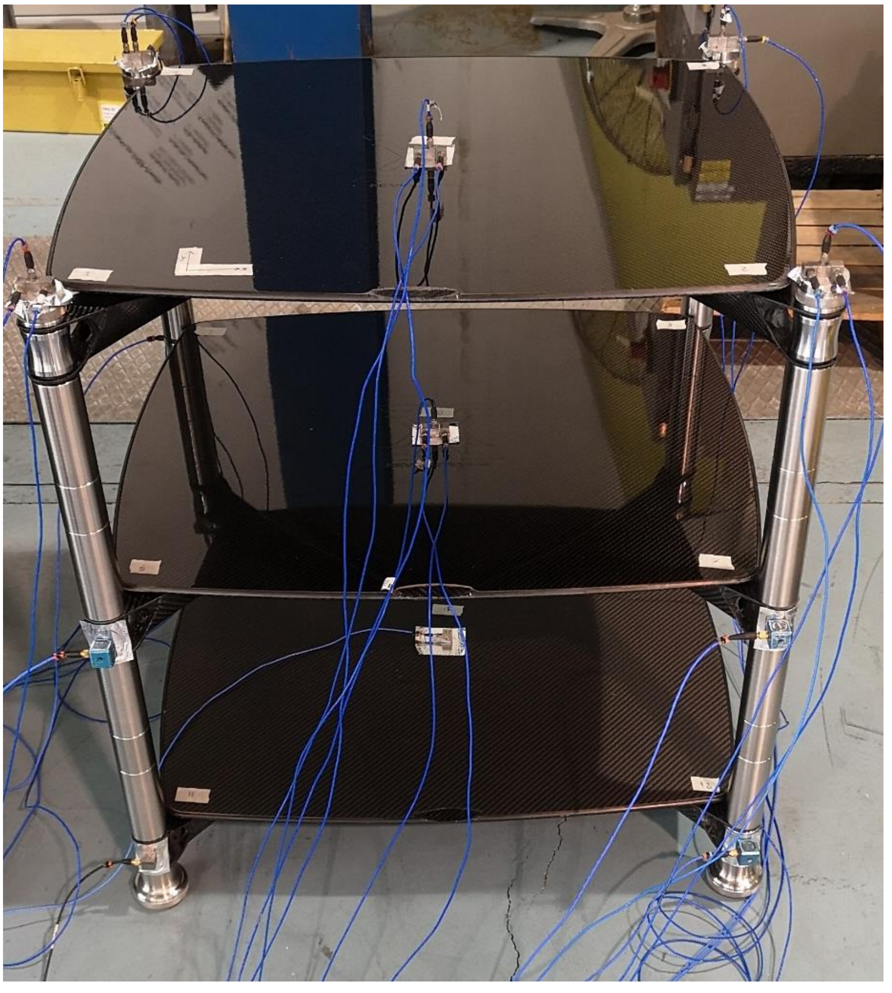


Figure 5. "Revolution X" –Modal tests in unloaded configuration.

Modal frequencies and corresponding damping are resumed in Table 1. Please note that the maximum observable frequency is equal to 114 Hz.

Mode ID	Revolution X	
	Frequency (Hz)	Damping (%)
1	7.230	2.80
2	8.085	3.57
3	9.351	3.11
4	27.083	9.45
5	35.092	2.06
6	43.402	1.96
7	49.483	1.58
8	57.456	5.51
9	63.719	2.56
10	69.050	2.34
11	82.711	4.06
12	96.171	3.88
13	114.078	2.30

Table 1. Resonance frequencies and damping measured on the "Revolution X" in unloaded configuration.

Figure 6 reports a graph of damping as a function of the frequency.

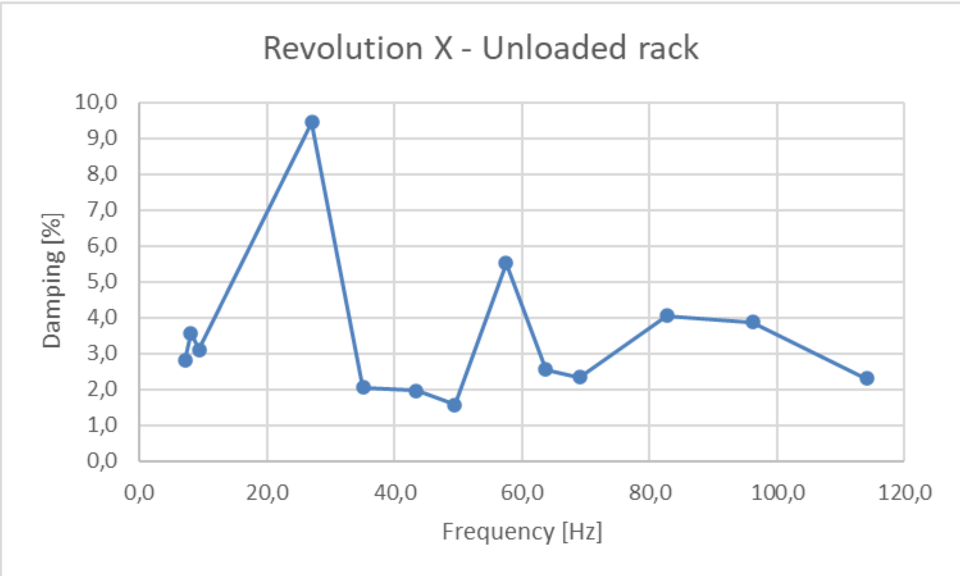


Figure 6. "Revolution X" – Damping vs. frequency – Unloaded rack.

Modal shapes of the first 7 modes of unloaded configuration, up to 50 Hz, are reported from Figure 7 to Figure 13.

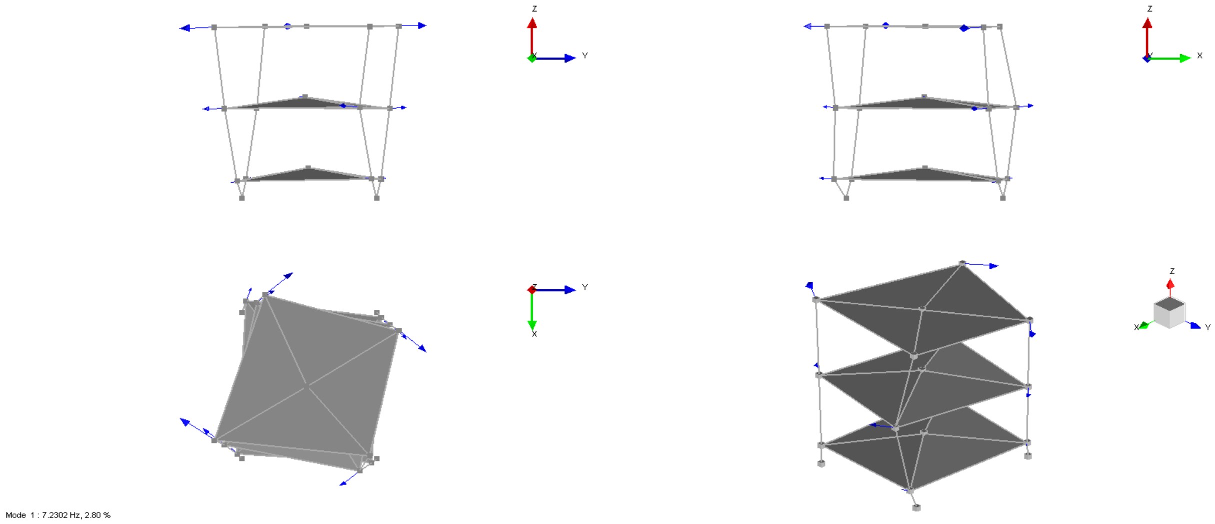


Figure 7. "Revolution X" – Mode 1 – Unloaded rack.

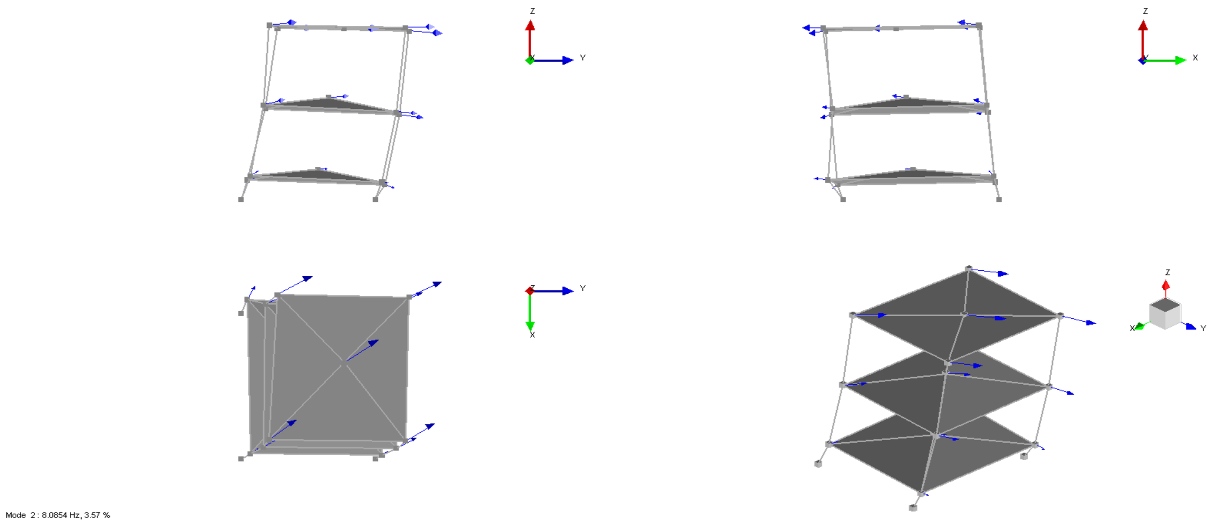


Figure 8. "Revolution X" – Mode 2 – Unloaded rack.

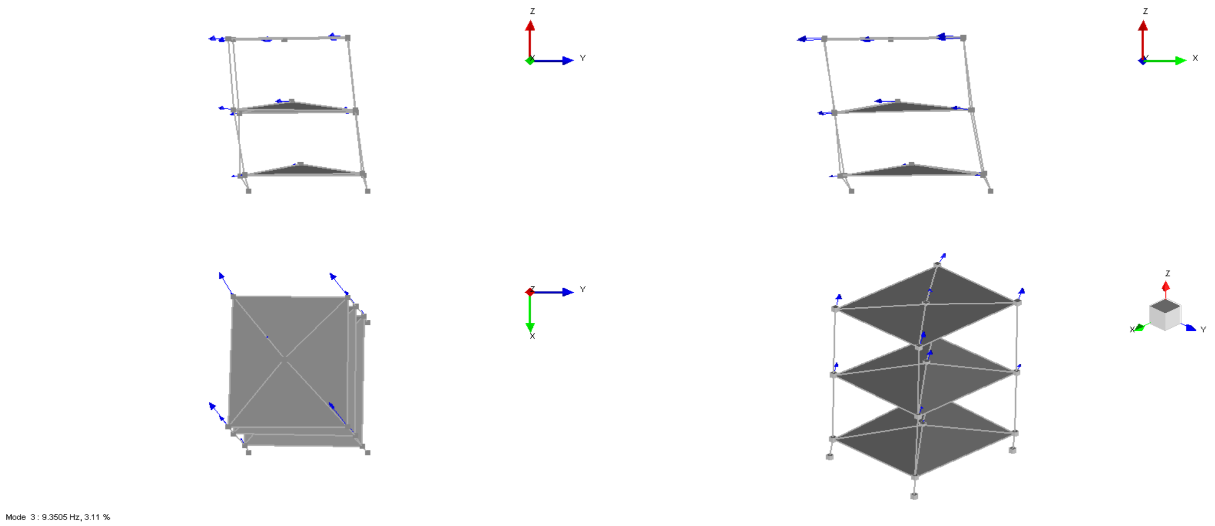
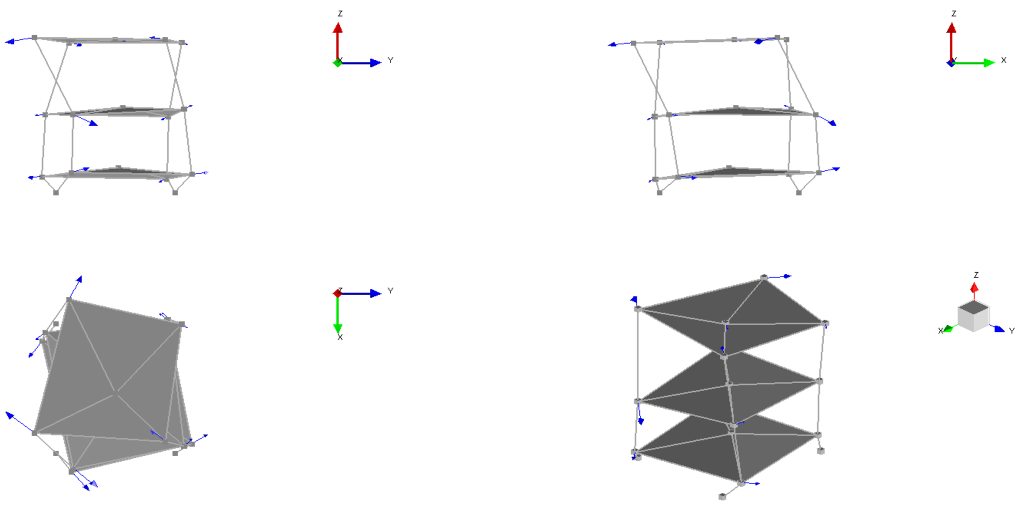
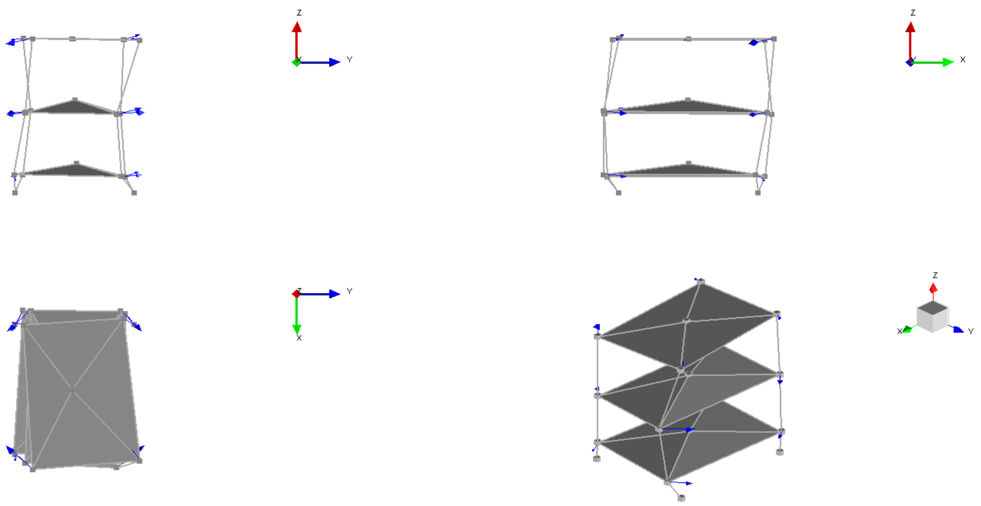


Figure 9. "Revolution X" – Mode 3 – Unloaded rack.



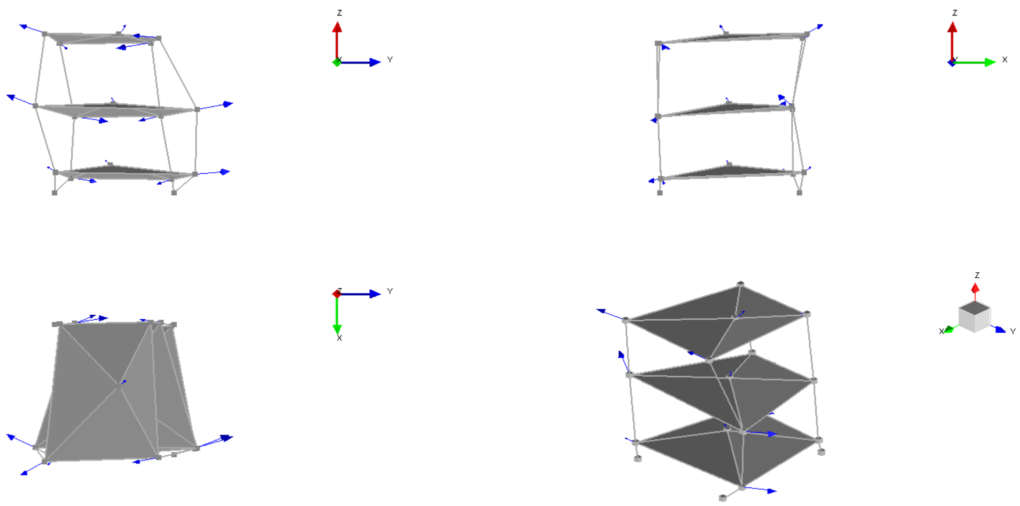
Mode 4 : 27.0828 Hz, 9.45 %

Figure 10. "Revolution X" – Mode 4 – Unloaded rack.



Mode 5 : 35.0919 Hz, 2.06 %

Figure 11. "Revolution X" – Mode 5 – Unloaded rack.



Mode 6 : 43.4021 Hz, 1.96 %

Figure 12. "Revolution X" – Mode 6 – Unloaded rack.

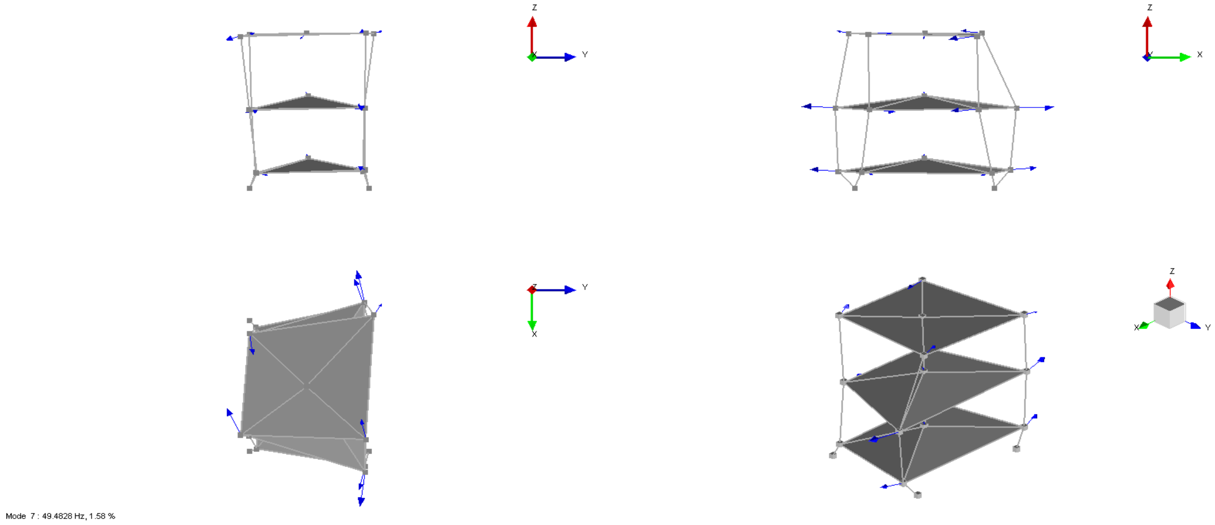


Figure 13. "Revolution X" – Mode 7 – Unloaded rack.

Modal tests on loaded rack

These tests are performed loading each shelf of the rack with 30 kg, as shown in Figure 14.

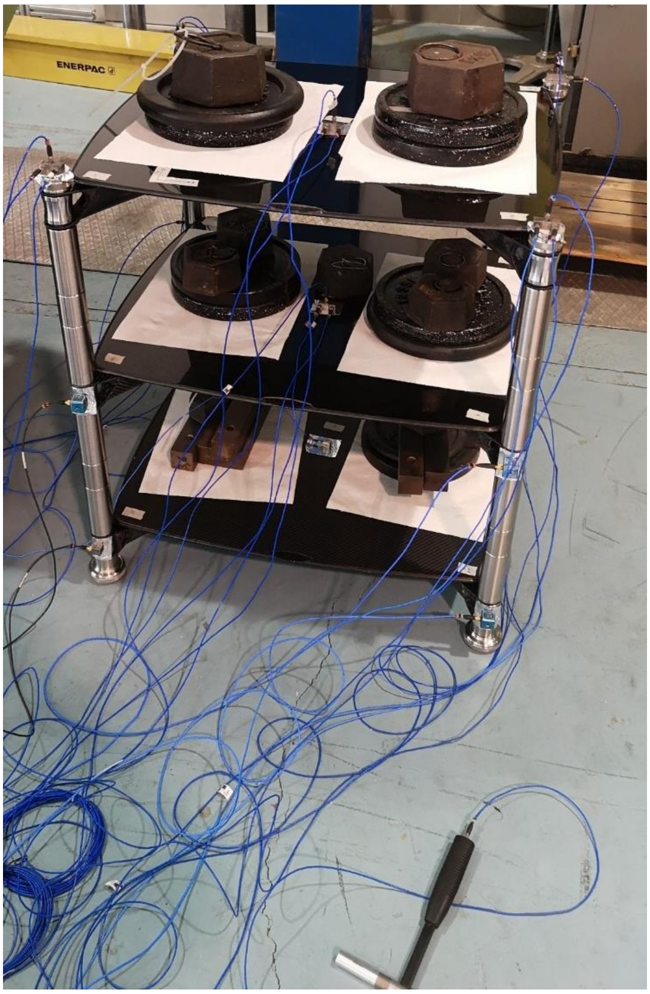


Figure 14. "Revolution X" - Modal tests in loaded configuration.

Modal frequencies and corresponding damping are resumed in Table 2. Please note that the maximum observable frequency is equal to 121 Hz.

Mode ID	Revolution X	
	Frequency (Hz)	Damping (%)
1	3.986	3.28
2	4.395	4.30
3	5.603	5.71
4	18.209	16.17
5	36.533	2.03
6	45.179	1.98
7	50.760	2.21
8	55.467	3.21
9	68.197	3.42
10	74.791	3.76
11	83.824	5.04
12	105.028	2.69
13	121.752	2.51

Table 2. Resonance frequencies and damping measured on the loaded rack.

Figure 17 reports a graph of damping as a function of the frequency.

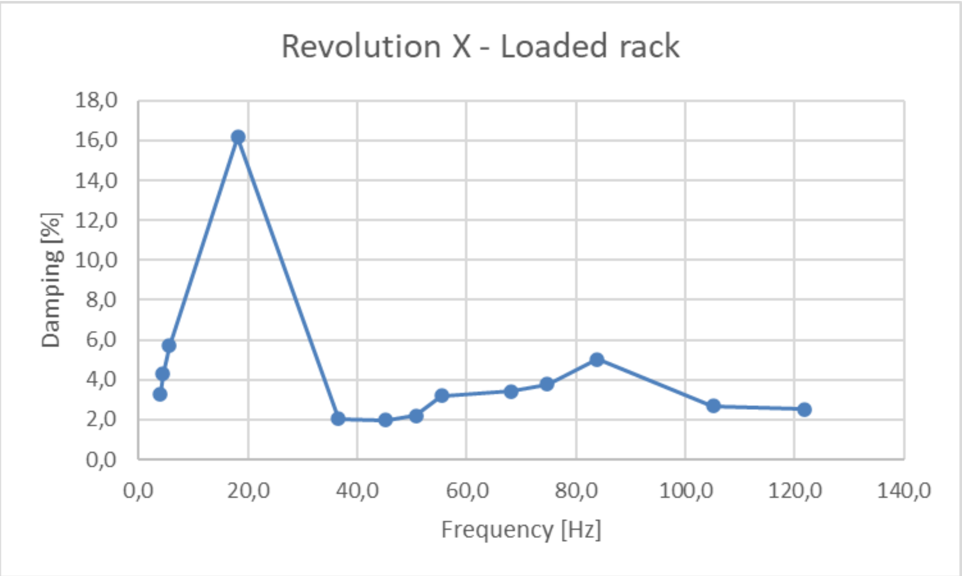


Figure 15. "Revolution X" – Damping vs. frequency – Loaded rack.

Modal shapes of the first seven modes of loaded configuration, up to 50 Hz, are reported in the figures from Figure 16 to Figure 22.

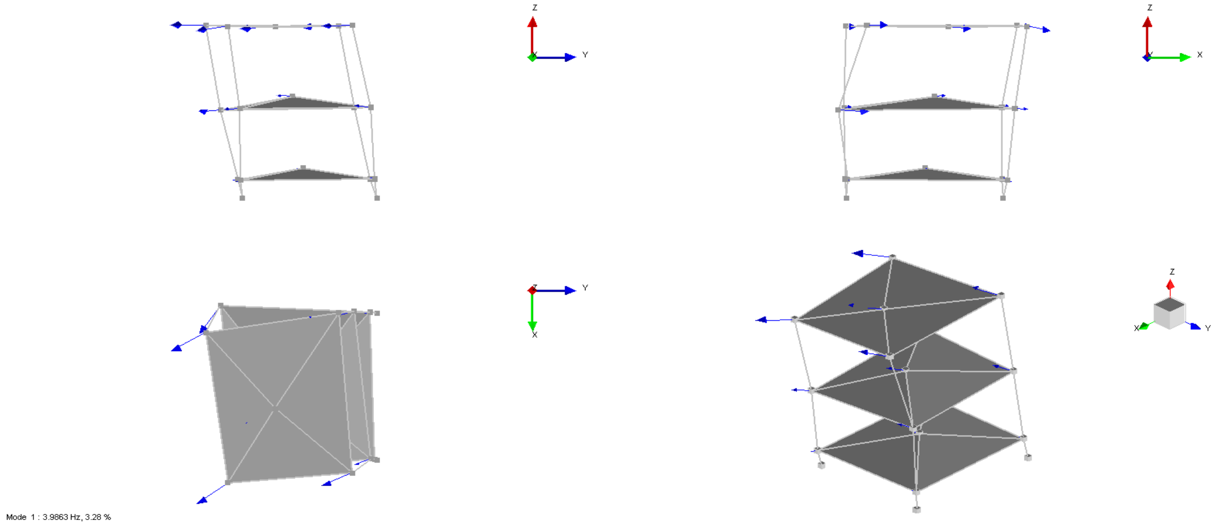


Figure 16. "Revolution X" – Mode 1 – Loaded configuration.

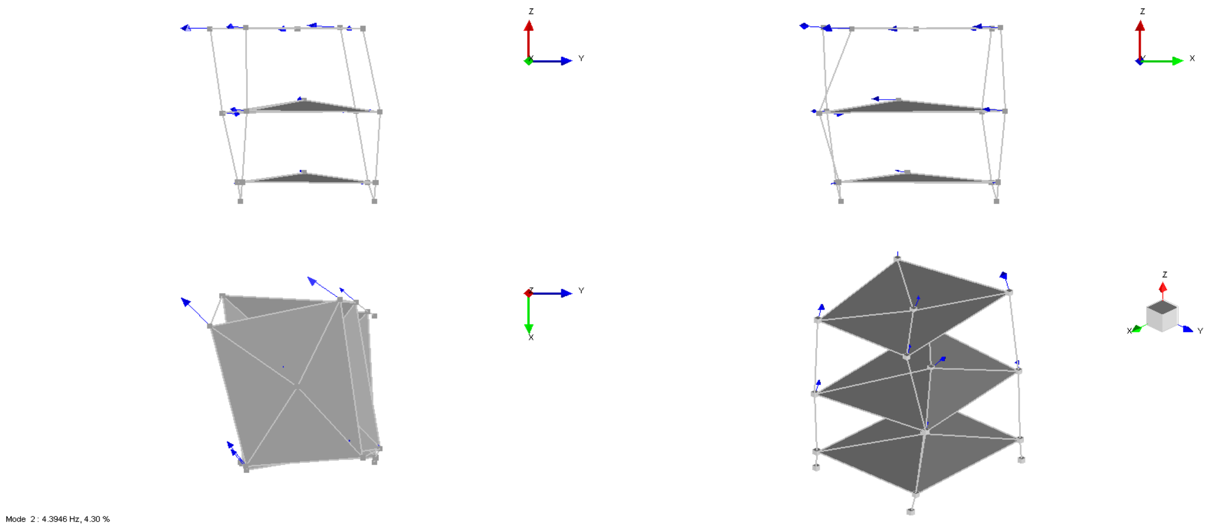


Figure 17. "Revolution X" – Mode 2 – Loaded configuration.

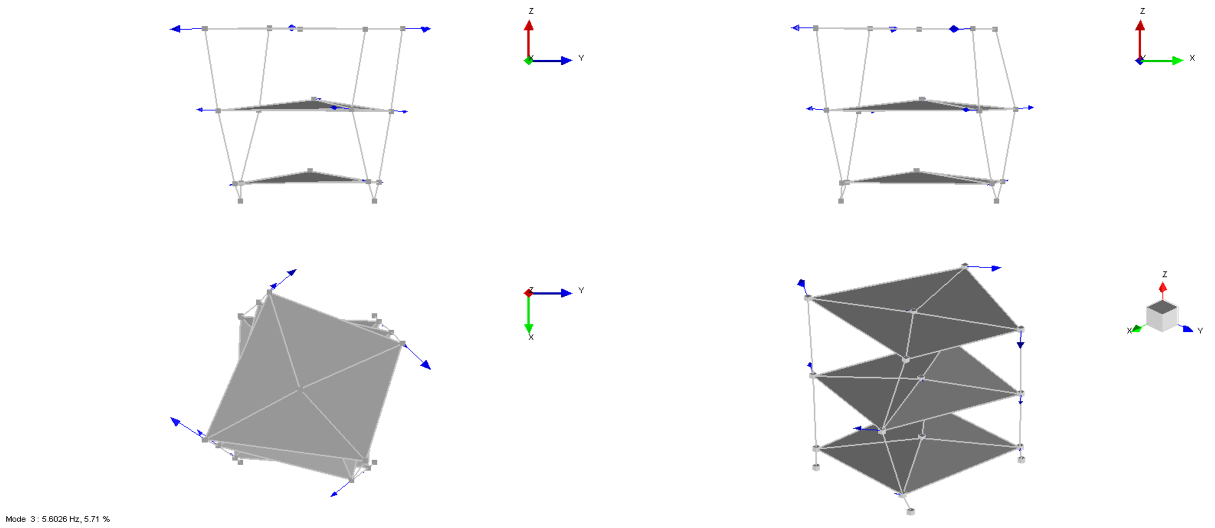


Figure 18. "Revolution X" – Mode 3 – Loaded configuration.

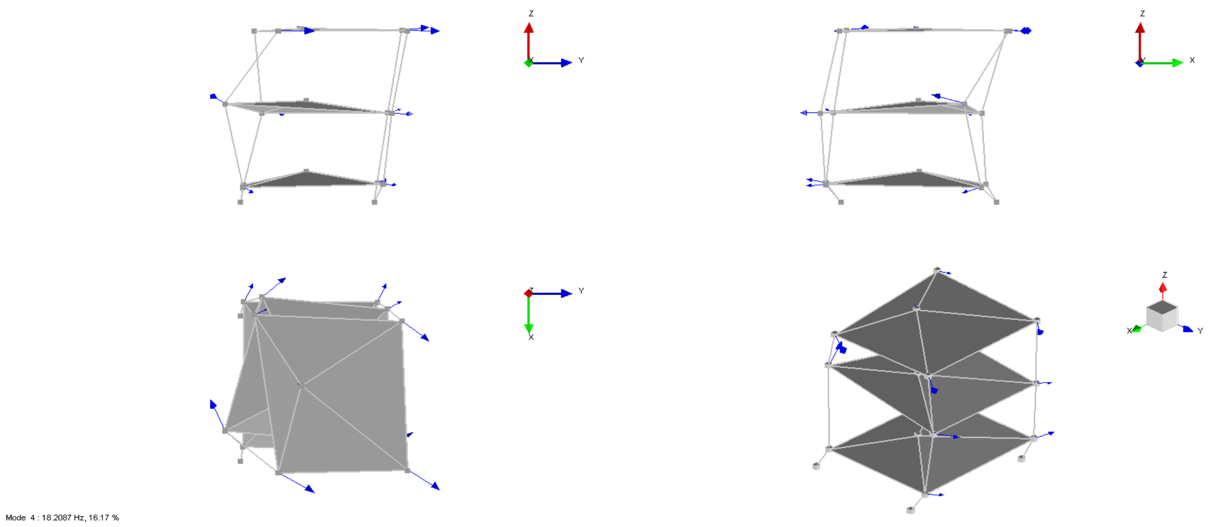


Figure 19. "Revolution X" – Mode 4 – Loaded configuration.

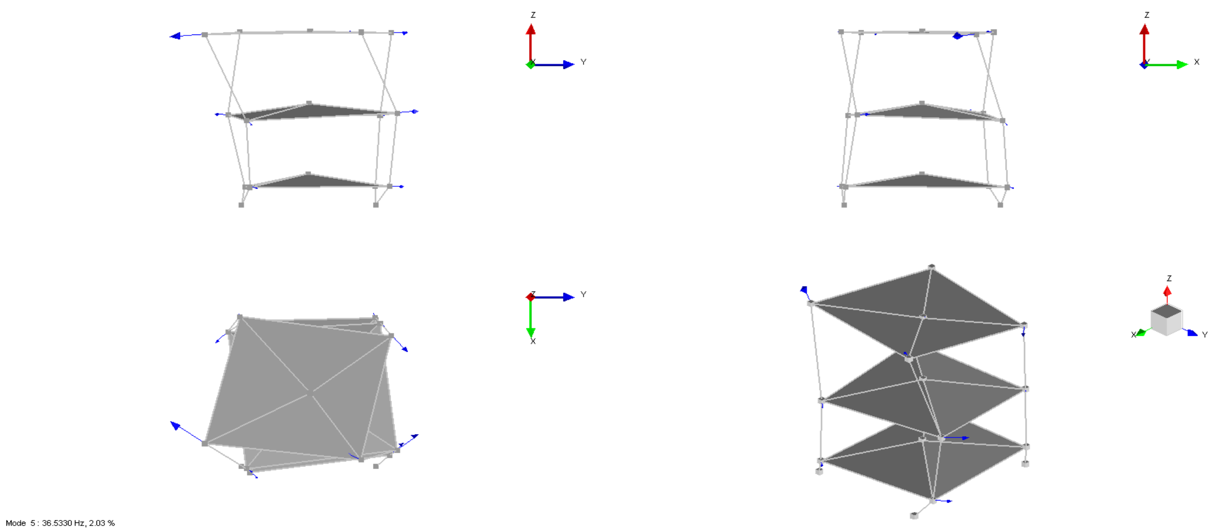


Figure 20. "Revolution X" – Mode 5 – Loaded configuration.

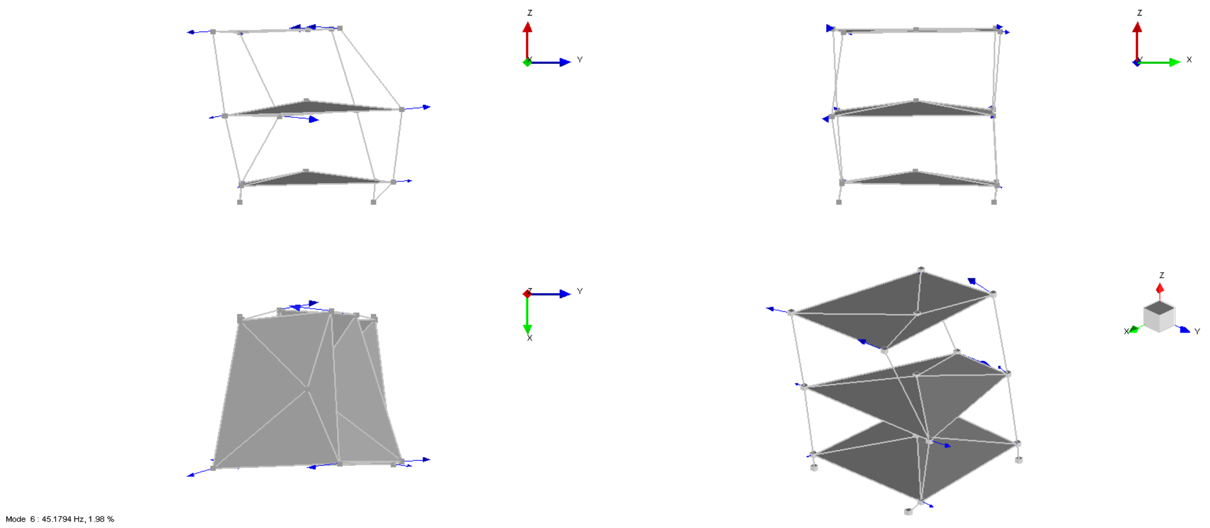


Figure 21. "Revolution X" – Mode 6 – Loaded configuration.

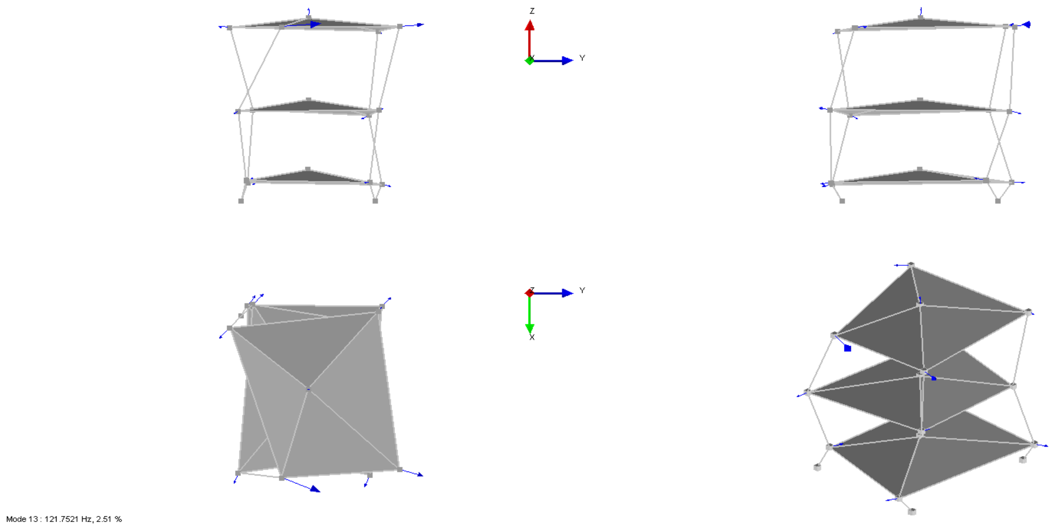


Figure 22. "Revolution X" – Mode 7 – Loaded configuration.

3. Static tests

3.1. Experimental setup

Two static tests are performed:

Test 1. Top shelf loading.

Test 2. Middle shelf loading.

Both tests are performed using calibrated weights to load the structure from 0 kg to 60 kg and vice-versa and the load vs. shortening curves are recorded.
Two Nippon Automation LAS-8010V laser sensors are used, with measuring range equal to 100 mm ± 40 mm, resolution of 50 µm and response time of 50 ms.
In the test 1 it is decided to measure both the shortening of the central point of the loaded shelf and the shortening of one column; in test 2 only the shortening of the of the central point of the loaded shelf is measured.
Figures from Figure 23 to Figure 26 show pictures of the rack during static tests.

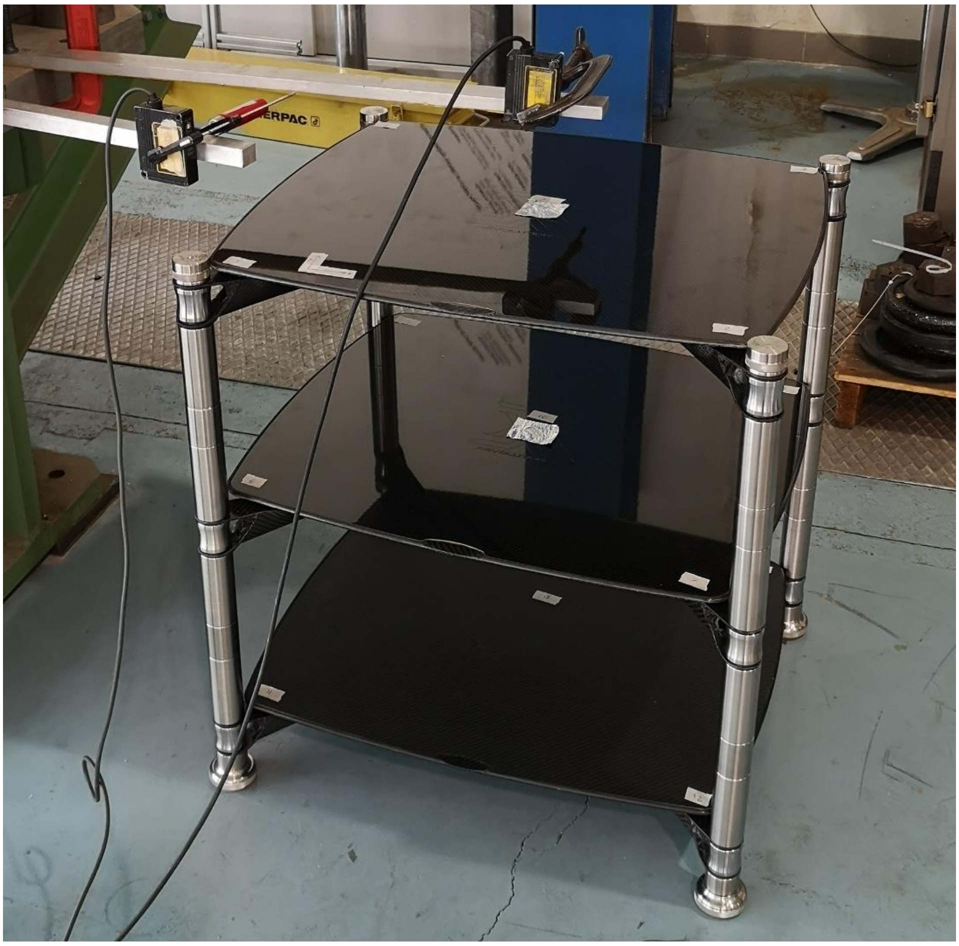


Figure 23. "Revolution X" during static tests – Top shelf loading configuration.

Figure 24. "Revolution X" during static tests – Top shelf loading.

Figure 25. "Revolution X" during static tests – Top shelf loading – Zoom.

Figure 26. "Revolution X" during static tests – Middle shelf loading.

3.2. Results

Obtained results are presented in the graphs from Figure 27 to Figure 29 and summarized in Table 3.

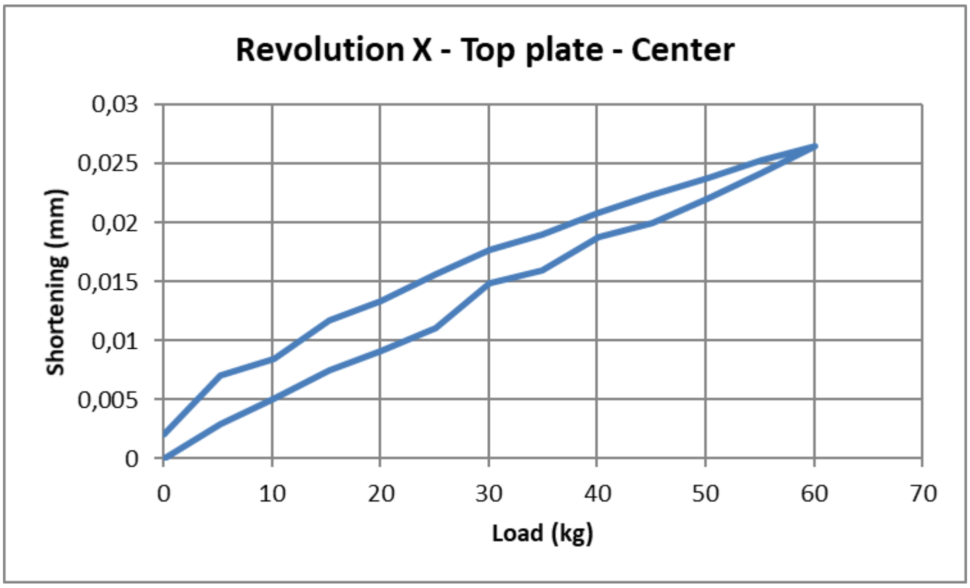


Figure 27. "Revolution X", test 1 – Shortening of central point as function of applied load.

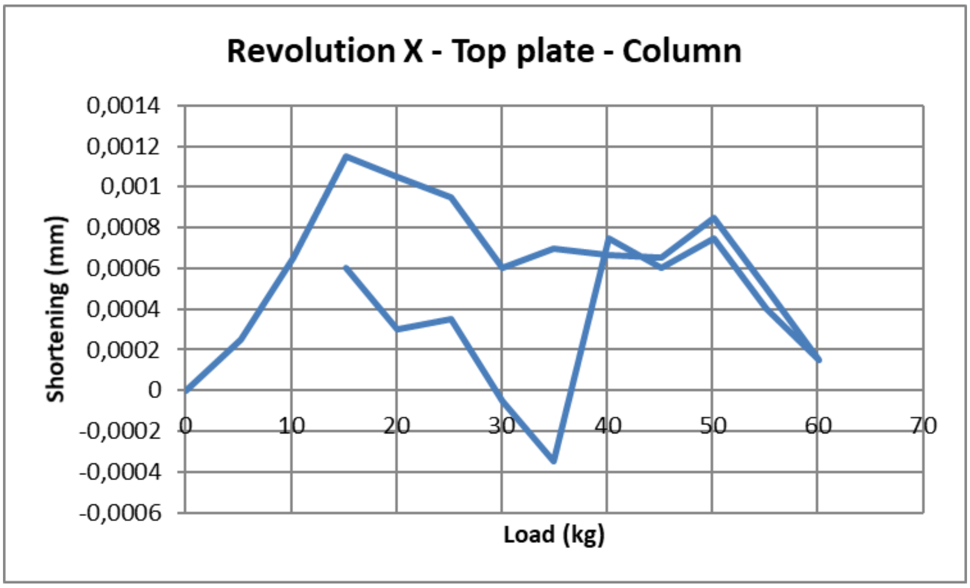


Figure 28. "Revolution X", test 1 – Shortening of corner point as function of applied load.

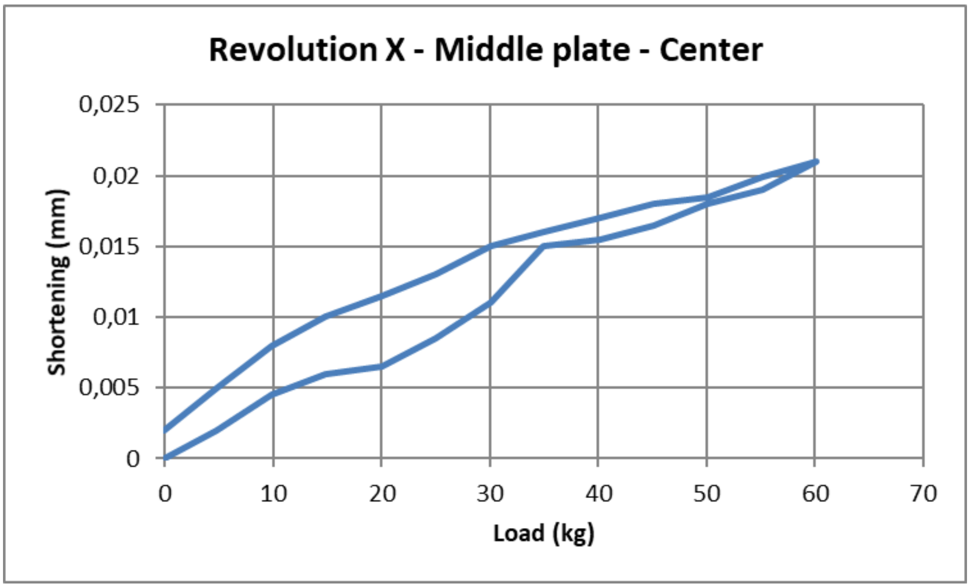


Figure 29. "Revolution X", test 2 – Shortening of central point as function of applied load.

Test type	Revolution X		Measuring point
	Maximum load (kg)	Maximum shortening (mm)	
1	60	0.026	Centre of top shelf
1	60	0.001	Rack's corner
2	60	0.021	Centre of middle shelf

Table 3. Static test results.

4. Conclusions

The “Revolution X” rack manufactured by Bassocontinuo showed excellent performances both from a dynamic and a static point of view.
Indeed, Vicoter was able to clearly identify only the natural frequencies up to 114 Hz in the unloaded configuration and up to 121 Hz in the loaded one. This means that, in the largest part of the audible band (20 Hz - 20 kHz), the rack does not have accentuated modal peaks; therefore, it does not significantly amplify any disturbances arriving from the outside.
Furthermore, from the static point of view, the rack showed excellent strength. Indeed, when loaded with 60 kg on the single shelf, it presented a maximum shortening lower than 0.026 mm of the shelf and a trivial shortening of the supporting columns.