Chapter 8
Some Non-conventional Boundary Conditions (From Marshmallows to Plungers: Who Would Have Guessed)

Tina Dardeno, Patrick Logan, and Peter Avitabile

Abstract When performing a modal test, a number of mechanisms are available to approximate the free-free boundary condition. Some test setups may be more difficult to implement than others, but ultimately the effect of the boundary condition on the actual modes of the system are of concern. An expensive setup may not be any better than an equivalent, inexpensive "Rube Goldberg" approach. In lieu of an expensive setup, a low cost, easily deployed configuration may be improvised from common objects not native to the test lab.

In this paper, several different boundary conditions are employed with two being very, very unconventional. The effects of the supports on the flexible modes are explored through testing with multiple support configurations. Natural frequencies and mode shapes of the modes (flexible and rigid body modes) are presented. Drive point frequency response functions for the different support configurations are compared. Some other considerations are discussed relative to the general items of concern when performing these types of free-free modal tests.

Keywords Modal testing techniques • Boundary conditions effects

8.1 Introduction

Often times, there is a need to test a structure in a free-free configuration. This is usually one of the more simple boundary conditions to achieve in a test lab. Typically a truly built-in condition is very hard to achieve due to the large, massive seismic type anchor that is needed. Free-free conditions are also used many times when correlating the test results with a finite element model; again this is a very easy boundary condition to simulate.

Now it is very easy to say "free-free" but many times how this is achieved in a practical lab setting may actually have an effect on the flexible modes of the system as well as the rigid body modes themselves [1]. There have been many, many different approaches to achieve this free-free condition and some have been very expensive. But the bottom line is how do the test boundary conditions affect the measured frequency, damping and mode shapes for the structure under test – that is the most critical question to answer [2, 3].

In some work involving correlation of the test data to the finite element model, analysts will often just use the analytical truly free condition. While this is very easy to do analytically, the practical reality is that the structure under test will actually have some type of spring support system which really needs to be modeled in order to be compared to the actual test data which has an actual "real" support system. If this is ignored then there can be improper characterization of the analytical frequencies and mode shapes identified from the model.

In order to illustrate some of the problems with the boundary conditions, three structures are evaluated. One is a simple frame type structure with very closely spaced frequencies for the first bending and first torsion of the frame which is a very common test scenario seen in many structures. The second structure is a cantilevered plate attached to a larger mass used to mimic some turbine blade qualification tests. The third structure is a shock response plate fixture. All of these structures use some very non-traditional test support systems as described in each test case.

T. Dardeno (✉) • P. Logan • P. Avitabile
Structural Dynamics and Acoustic Systems Laboratory, University of Massachusetts Lowell, One University Avenue, Lowell, MA 01854, USA
e-mail: tina_dardeno@student.uml.edu

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8.2 Frame Structure with Marshmallow Supports

The dynamic characterization of the small aluminum frame was determined with the frame placed on four large marshmallows and again with the frame placed on ten small marshmallows. The marshmallows provide a reasonably good free-free condition but there is some effect on the type and location of the marshmallows used. Data gathering was performed with the frame located on a seismic anchor (Fig. 8.1).

For the four large marshmallows test, the marshmallows were placed in the center of each side of the frame, as shown in Fig. 8.1. For the ten small marshmallows test, four marshmallows were placed beneath the long end of the frame and one marshmallow was placed beneath the short end of the frame as shown in Fig. 8.1.

Two teardrop accelerometers were placed on the frame: one beneath point one and another beneath point seven. A modally tuned impact hammer with a white plastic tip was used to excite the frame at 16 locations. All measurements and impacts were performed in the +Z direction (Fig. 8.2).

Nine flexible modes were evaluated over a bandwidth of 2,000 Hz using Photon software via LDS Dactron. Data was then processed in LMS (Fig. 8.3).

Figure 8.3 shows that the first and second modes were swapped depending on the boundary conditions. Specifically, the first and second modes for the four large marshmallow test were bending and torsional modes, respectively. Conversely, for the ten small marshmallow test, the first mode was a torsional mode and the second was a bending mode.

The natural frequencies and damping of the two tests are compared in Table 8.1.

Table 8.1 shows that the natural frequencies associated with the flexible modes remained relatively constant with both boundary conditions. The frequency difference between the first and second modes was greater for the ten small marshmallows test (1.72 Hz) compared to the four large marshmallows test (0.275 Hz), indicating greater overlap of modes for the four large marshmallows test. Furthermore, the large marshmallow test produced frequencies slightly lower than those obtained with the small marshmallow test. This frequency shift implies that the small marshmallow configuration produced greater stiffness than the large marshmallows. However, the large marshmallows produced greater damping for all but the second and fifth modes compared to the small marshmallow configuration.

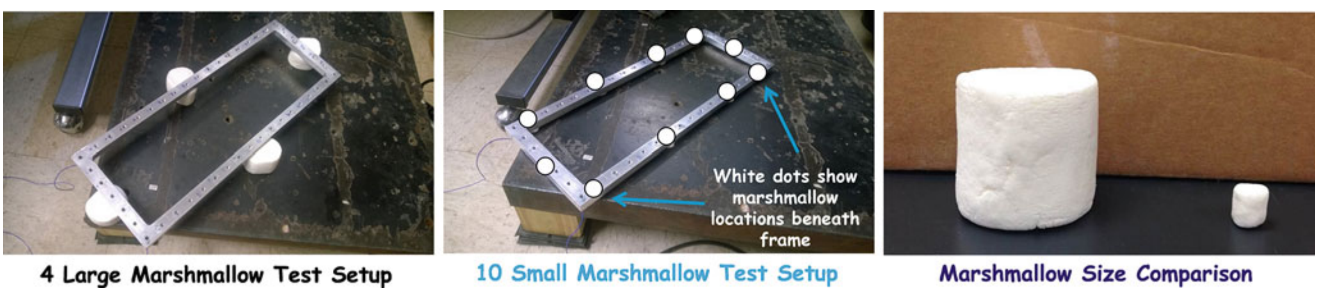

Fig. 8.1 Testing configuration for aluminum frame on four large marshmallows and on ten small marshmallows

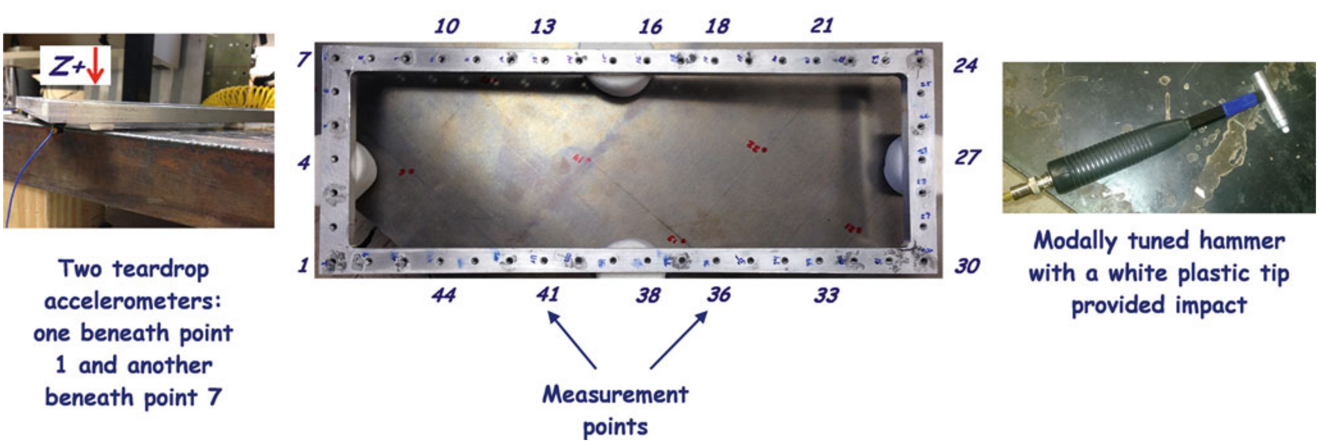

Fig. 8.2 Measurement points and instrumentation for four large marshmallow and ten small marshmallow tests

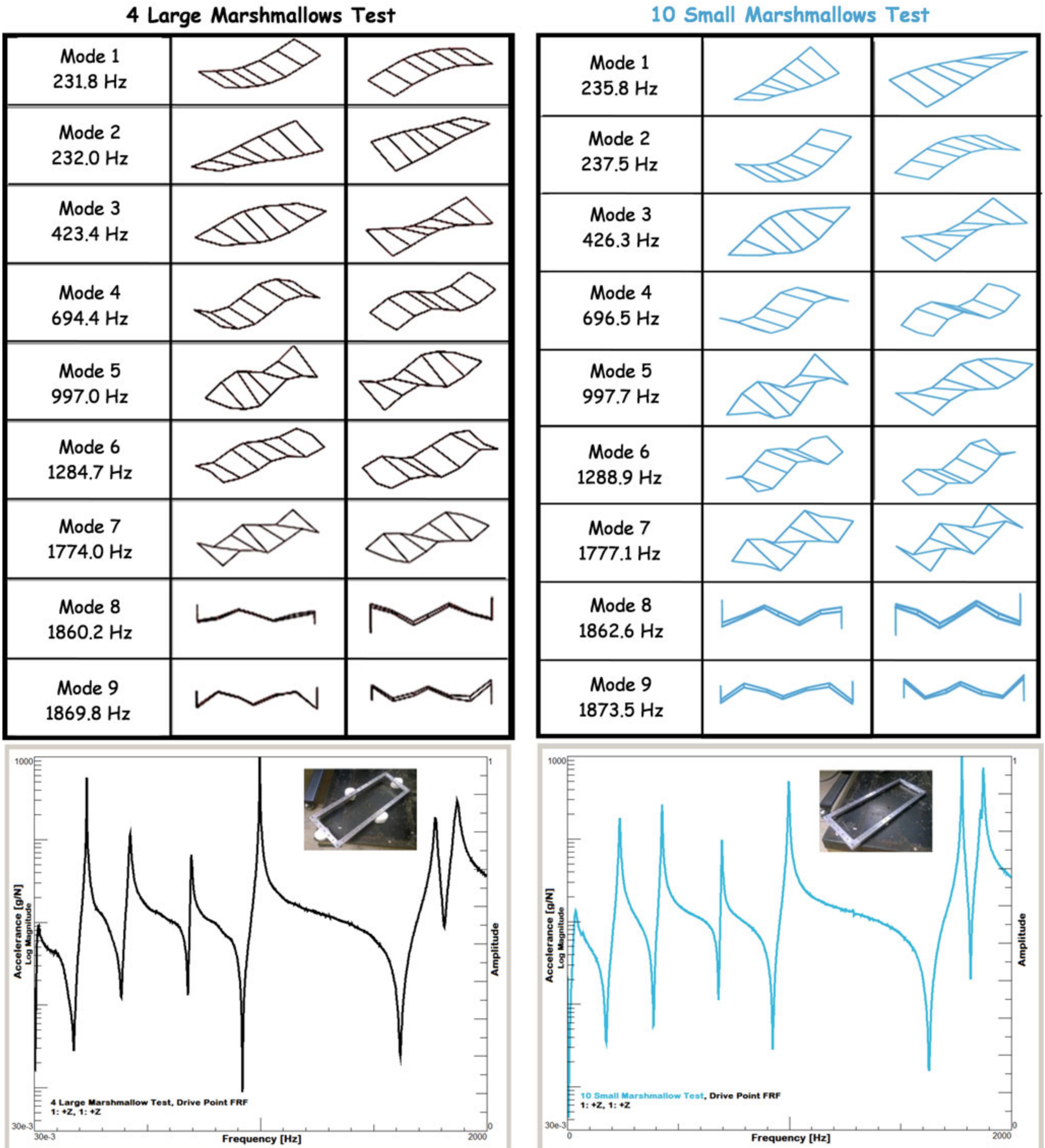

Fig. 8.3 Results of four large marshmallow test and ten small marshmallow test

From Fig. 8.3, the large marshmallows were located at the node points of the first torsion mode. Different marshmallow locations were selected to create a boundary condition with more of an effect for the first torsion mode. The experiment was repeated with the large marshmallows located at the corners of the frame (Fig. 8.4). The same equipment and testing parameters were used.

Table 8.1 Natural frequencies and damping for four large marshmallow test and ten small marshmallow test

	Frequency (Hz)			Damping (% critical)		
Mode	Four large marshmallows	Ten small marshmallows	% difference	Four large marshmallows	Ten small marshmallows	% difference
1	231.766	235.784	1.72 %	2.31	1.14	67.83 %
2	232.041	237.502	2.33 %	0.16	1.12	150.00 %
3	423.397	426.309	0.69 %	0.96	0.43	76.26 %
4	694.349	696.520	0.31 %	0.38	0.29	26.87 %
5	996.980	997.680	0.07 %	0.07	0.27	117.65 %
6	1,284.748	1,288.930	0.32 %	0.57	0.11	135.29 %
7	1,774.023	1,777.070	0.17 %	0.33	0.05	147.37 %
8	1,860.231	1,862.640	0.13 %	0.37	0.18	69.09 %
9	1,869.836	1,873.460	0.19 %	0.42	0.13	105.45 %

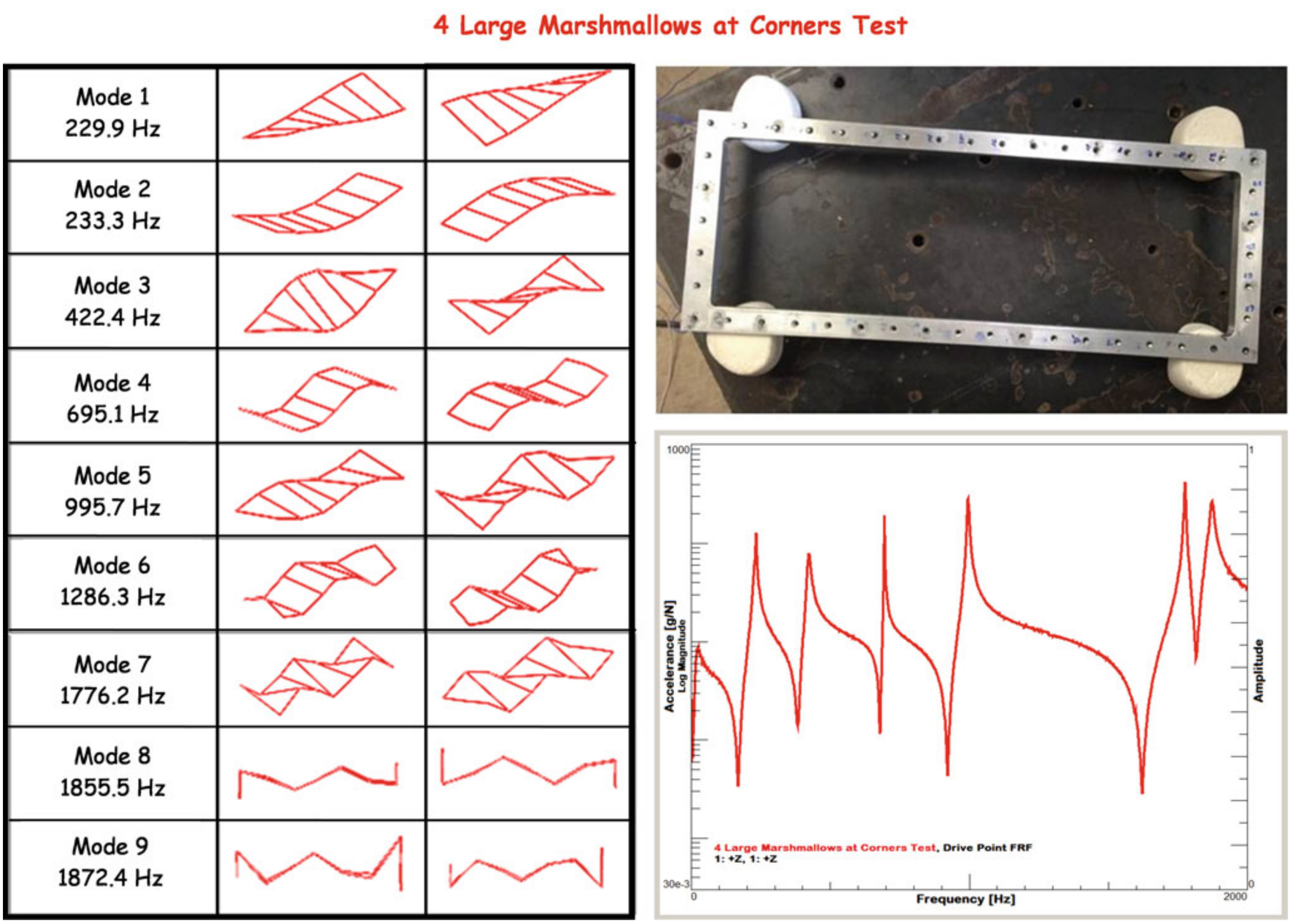

Fig. 8.4 Results of four large marshmallows at corners test

Figure 8.4 shows that moving the four large marshmallows to the corners of the frame resulted in the first torsional mode occurring at a lower frequency than the first bending mode, as was seen with the ten small marshmallows test. Figure 8.5 compares the first two modes of all three tests.

The natural frequencies and damping of the four large marshmallows at the corners test are compared to that of the ten small marshmallows test in Table 8.2. Compared to the ten small marshmallows test, the four large marshmallows at the corners test produced lower frequencies. However, the large marshmallows at the corners test produced greater damping for all but the second and fifth modes compared to the small marshmallow configuration.

The natural frequencies and damping of the four large marshmallows at the corners test are compared to that of the original four large marshmallows test in Table 8.3. Compared to the original large marshmallows test, the four large marshmallows

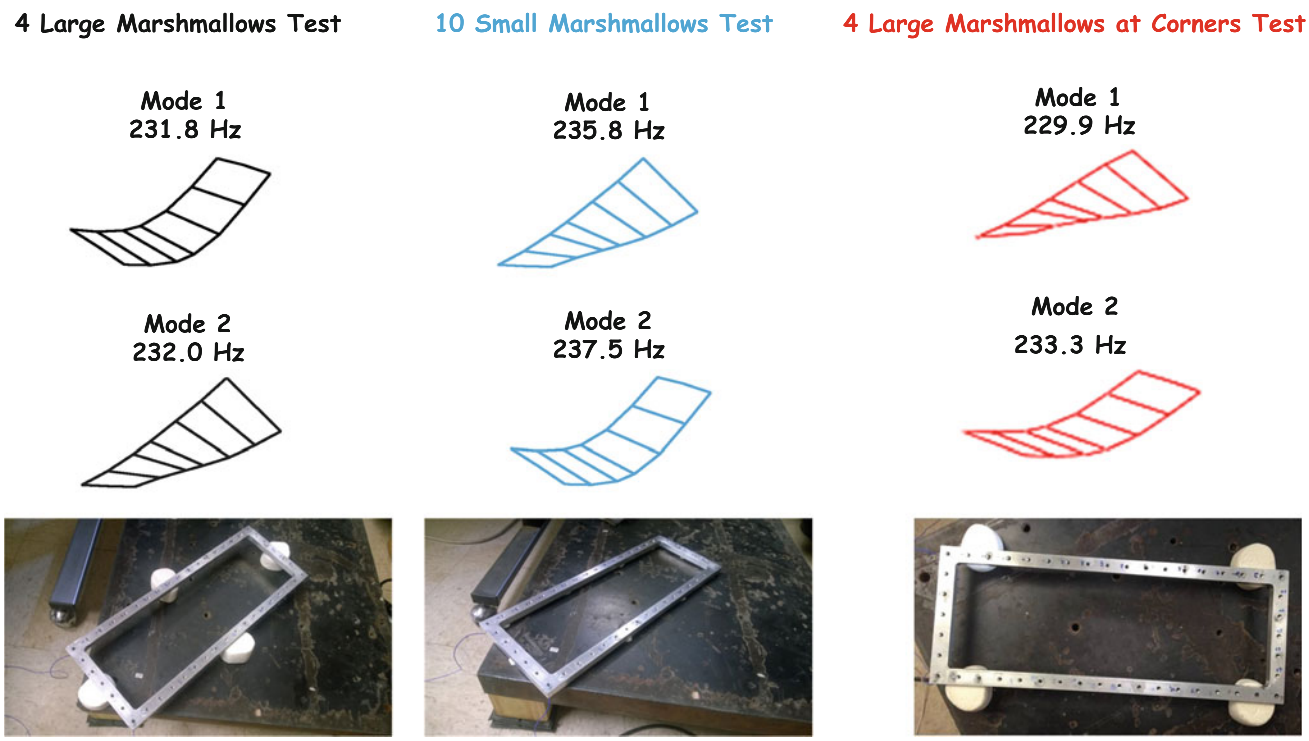

Fig. 8.5 Results comparison for different marshmallow boundary conditions

Table 8.2 Natural frequencies and damping for four large marshmallows at corners test and ten small marshmallows test

	Frequency (Hz)			Damping		
Mode	Four large marshmallows at corners	Ten small marshmallows	% difference	Four large marshmallows at corners	Ten small marshmallows	% difference
1	229.910	235.784	2.52 %	3.11	1.14	92.71 %
2	233.318	237.502	1.78 %	0.76	1.12	38.30 %
3	422.352	426.309	0.93 %	1.55	0.43	113.13 %
4	695.133	696.520	0.20 %	0.15	0.29	63.64 %
5	995.690	997.680	0.20 %	0.35	0.27	25.81 %
6	1,286.290	1,288.930	0.21 %	0.51	0.11	129.03 %
7	1,776.203	1,777.070	0.05 %	0.15	0.05	100.00 %
8	1,855.454	1,862.640	0.39 %	0.60	0.18	107.69 %
9	1,872.439	1,873.460	0.05 %	0.38	0.13	98.04 %

Table 8.3 Natural frequencies and damping for four large marshmallows at corners test and four large marshmallows test

	Frequency (Hz)			Damping		
Mode	Four large marshmallows at corners	Four large marshmallows	% difference	Four large marshmallows at corners	Four large marshmallows	% difference
1	229.910	231.766	0.80 %	3.11	2.31	29.52 %
2	233.318	232.041	0.55 %	0.76	0.16	130.43 %
3	422.352	423.397	0.25 %	1.55	0.96	47.01 %
4	695.133	694.349	0.11 %	0.15	0.38	86.79 %
5	995.690	996.980	0.13 %	0.35	0.07	133.33 %
6	1,286.290	1,284.748	0.12 %	0.51	0.57	11.11 %
7	1,776.203	1,774.023	0.12 %	0.15	0.33	75.00 %
8	1,855.454	1,860.231	0.26 %	0.60	0.37	47.42 %
9	1,872.439	1,869.836	0.14 %	0.38	0.42	10.00 %

Table 8.4 MAC for all marshmallow tests

		4 Large Marshmallows Test									10 Small Marshmallows Test									4 Large Marshmallows at Corners Test								
		1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
4 Large Marshmallows Test	1	100	3.26	0.01	0.33	0.02	9.9	0	0.8	3.19	7.73	92.91	0.14	0.42	0.02	8.92	0.01	0.84	4.17	0.17	97.07	0.03	0.35	0.01	8.49	0.02	0.42	3.04
	2	3.26	100	0.19	0.02	0.35	1.67	0.01	0.05	0.21	92.25	6.18	0.3	0.14	0.14	0.28	0.1	0.01	0.03	96.25	0.02	0.28	0.04	0.22	0.18	0.07	0.08	0.12
	3	0.01	0.19	100	0	0.38	0.14	0.23	0.06	0	0.19	0.17	99.66	0	0.46	0.21	0.06	0.02	0	0.18	0.03	99.74	0	0.38	0.15	0.09	0.01	0
	4	0.33	0.02	0	100	0.13	0.32	0.07	5.55	0.39	0.03	0.35	0	99.8	0.15	0.15	0.01	6.59	0.16	0.04	0.37	0	99.83	0.09	0.36	0.04	6.37	0.27
	5	0.02	0.35	0.38	0.13	100	0.49	0.25	0.04	0.01	0.48	0.03	0.24	0.24	99	0.5	0.13	0.01	0.04	0.48	0.03	0.32	0.11	98.9	0.03	0.37	0.18	0.02
	6	9.9	1.67	0.14	0.32	0.49	100	0.18	4.63	1.21	0.11	9.82	0.33	0.31	0.75	88.59	0.11	0.25	2.28	1.07	9.06	0.16	0.38	0.89	86.9	0.23	0.89	2.2
	7	0	0.01	0.23	0.07	0.25	0.18	100	0.09	0.1	0.01	0.01	0.11	0.05	0.23	0.04	99.61	0.03	0.07	0.03	0	0.19	0.01	0.31	0.28	99.56	0.23	0.1
	8	0.8	0.05	0.06	5.55	0.04	4.63	0.09	100	1.69	0.07	0.8	0.11	4.58	0.03	2.94	0.06	93.88	0.73	0.13	0.82	0.09	4.89	0.01	1.6	0.05	86.83	4.92
	9	3.19	0.21	0	0.39	0.01	1.21	0.1	1.69	100	0.88	2.39	0	0.29	0	0.58	0.01	0.87	97.36	0.23	2.98	0.01	0.4	0	0.6	0.08	16.68	97.07
10 Small Marshmallows Test	1	7.73	92.25	0.19	0.03	0.48	0.11	0.01	0.07	0.88	100	0.05	0.24	0.15	0.03	0.18	0.04	0.06	0.33	93.95	7.11	0.27	0.06	0.06	0.22	0.02	0.1	0.61
	2	92.91	6.18	0.17	0.35	0.03	9.82	0.01	0.8	2.39	0.05	100	0.54	0.51	0.01	8.01	0.07	0.69	3.61	4.92	93.66	0.27	0.37	0.01	7.63	0.06	0.28	2.38
	3	0.14	0.3	99.66	0	0.24	0.33	0.11	0.11	0	0.24	0.54	100	0	0.3	0.46	0.01	0	0	0.28	0.21	99.76	0	0.23	0.33	0.02	0	0
	4	0.42	0.14	0	99.8	0.24	0.31	0.05	4.58	0.29	0.15	0.51	0	100	0.27	0.15	0.01	5.51	0.09	0.15	0.47	0.02	99.87	0.19	0.36	0.03	5.26	0.16
	5	0.02	0.14	0.46	0.15	99	0.75	0.23	0.03	0	0.03	0.01	0.3	0.27	100	0.41	0.11	0	0.01	0.14	0.01	0.38	0.14	99.91	0.02	0.34	0.12	0
	6	8.92	0.28	0.21	0.15	0.5	88.59	0.04	2.94	0.58	0.18	8.01	0.46	0.15	0.41	100	0.02	0.09	0.03	0.16	8.55	0.23	0.21	0.66	97.41	0.11	0.16	0.1
	7	0.01	0.1	0.06	0.01	0.13	0.11	99.61	0.06	0.01	0.04	0.07	0.01	0.01	0.11	0.02	100	0.01	0	0.14	0.01	0.04	0.01	0.16	0.24	99.65	0.22	0.01
	8	0.84	0.01	0.02	6.59	0.01	0.25	0.03	93.88	0.87	0.06	0.69	0	5.51	0	0.09	0.01	100	0.32	0.02	0.85	0	5.79	0	0.37	0	87.12	0.89
	9	4.17	0.03	0	0.16	0.04	2.28	0.07	0.73	97.36	0.33	3.61	0	0.09	0.01	0.03	0	0.32	100	0.02	4.07	0	0.16	0.01	0.04	0.05	10.17	97.33
4 Large Marshmallows at Corners Test	1	0.17	96.25	0.18	0.04	0.48	1.07	0.03	0.13	0.23	93.95	4.92	0.28	0.15	0.14	0.16	0.14	0.02	0.02	100	2.93	0.26	0.04	0.22	0.26	0.09	0.06	0.11
	2	97.07	0.02	0.03	0.37	0.03	9.06	0	0.82	2.98	7.11	93.66	0.21	0.47	0.01	8.55	0.01	0.85	4.07	2.93	100	0.06	0.37	0	8.24	0.01	0.37	2.9
	3	0.03	0.28	99.74	0	0.32	0.16	0.19	0.09	0.01	0.27	0.27	99.76	0.02	0.38	0.23	0.04	0	0	0.26	0.06	100	0.01	0.3	0.16	0.07	0	0
	4	0.35	0.04	0	99.83	0.11	0.38	0.01	4.89	0.4	0.06	0.37	0	99.87	0.14	0.21	0.01	5.79	0.16	0.04	0.37	0.01	100	0.08	0.41	0	5.64	0.25
	5	0.01	0.22	0.38	0.09	98.9	0.89	0.31	0.01	0	0.06	0.01	0.23	0.19	99.91	0.66	0.16	0	0.01	0.22	0	0.3	0.08	100	0.01	0.42	0.1	0
	6	8.49	0.18	0.15	0.36	0.03	86.9	0.28	1.6	0.6	0.22	7.63	0.33	0.36	0.02	97.41	0.24	0.37	0.04	0.26	8.24	0.16	0.41	0.01	100	0.44	0.21	0.08
	7	0.02	0.07	0.09	0.04	0.37	0.23	99.56	0.05	0.08	0.02	0.06	0.02	0.03	0.34	0.11	99.65	0	0.05	0.09	0.01	0.07	0	0.42	0.44	100	0.17	0.11
	8	0.42	0.08	0.01	6.37	0.18	0.89	0.23	86.83	16.68	0.1	0.28	0	5.26	0.12	0.16	0.22	87.12	10.17	0.06	0.37	0	5.64	0.1	0.21	0.17	100	17.99
	9	3.04	0.12	0	0.27	0.02	2.2	0.1	4.92	97.07	0.61	2.38	0	0.16	0	0.1	0.01	0.89	97.33	0.11	2.9	0	0.25	0	0.08	0.11	17.99	100

at the corners test produced similar frequencies. The frequency difference between the first and second modes, however, increased from 0.275 to 3.41 Hz, better aligning with that of the small marshmallows test. The large marshmallows at the corners test produced greater damping at the first, second, third, fifth, and eighth modes. The increased damping at the first torsional mode is expected as the marshmallows were moved from the node line to the corners where maximum displacement occurred. Discrepancies in damping at the other modes are likely due to similar movement of the supports either closer to or further from node lines or differences in data processing. In addition, moving the large marshmallows inward towards the center of the frame produced greater damping. Therefore, differences in how the marshmallows were arranged with respect to the center of the frame may have caused some discrepancy. However, an effort was made to be consistent between the tests. Additional mode comparison for the three tests can be found in Table 8.4.

These three tests show that the boundary condition may have an important effect on the frequencies of the modes as well as the organization and damping of the modes. Therefore, when performing a test on a "free-free" object, one must not only be cautious about the shifting of frequencies but also about the organization of the modes due to the test setup. Overall the marshmallows provided a very useful free-free boundary condition support.

8.3 Upright Cantilever Calibration Structure on Pads

The upright cantilever calibration structure is a plate bolted into a block with a much larger mass; this is similar to a test configuration for small turbine blade qualification tests. The structure is generally tested on padded material to minimize the effects of any incompatibilities between the bottom of the structure and the work surface. Experiments with the calibration structure had previously been performed, but with different types of padding. In attempting to compare results, the question arose as to the effects of the different types of padded material on the flexible modes. The structure is shown in Fig. 8.6.

Experimental mode shapes for the structure, obtained from prior testing at 25 points, are shown in Fig. 8.7aa. A drive point FRF, and input and coherence spectra from point 45 are shown in Fig. 8.7b. For this supplemental investigation, six points were selected for study based on the locations of maximum responsiveness of the various flexible modes.

Impact testing was performed with a mini impact hammer at points 11, 15, 21, 25, 41, 45. The impact hammer was mounted to a tripod (with a Dunkin Donuts® straw) to maintain a very consistent impact location on the structure. In addition,

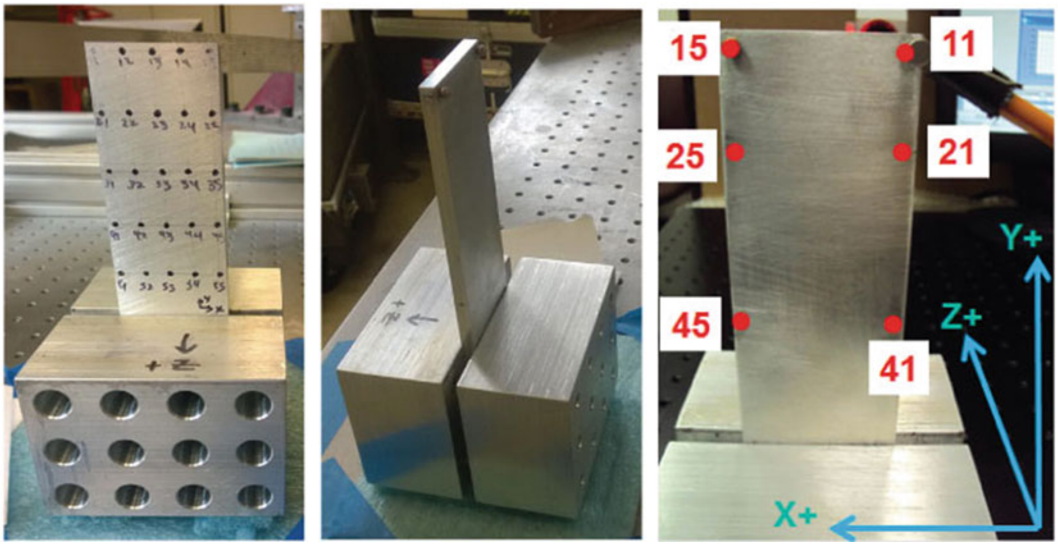

Fig. 8.6 Calibration structure, from the front, side and rear, with impact points and coordinate axes

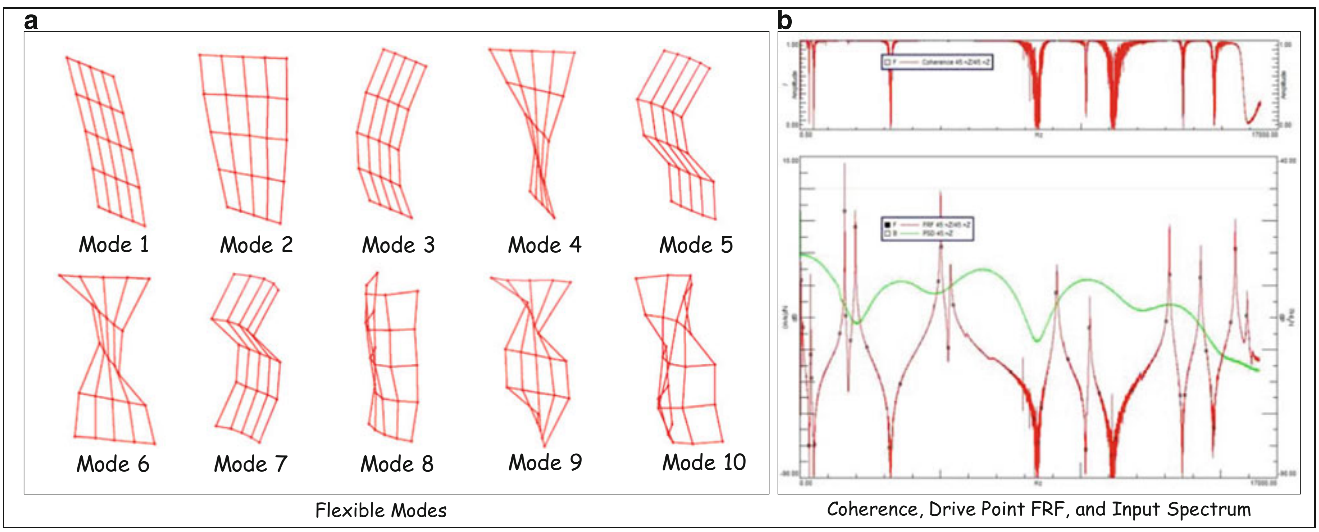

Fig. 8.7 (**a**) Flexible mode shapes of upright cantilever structure obtained from prior testing and (**b**) typical coherence, drive point FRF, and input spectrum obtained during prior testing

impacts at points 11 and 15 were made through ball bearings previously glued to the structure for testing with larger impact hammers; this further controls the accuracy of the impact location. Response was measured at point 11 with a laser. For each point, 10 averages were taken over a 20 kHz bandwidth with a Data Physics Quattro Dynamic Signal Analyzer. Acquisition time was 1.28 s for each measurement. A force-exponential window was employed to reduce the effects of the structure ringing. Data processing was performed in LMS. The impact hammer and laser setup are shown in Fig. 8.8. The structure was tested on 4¾ in. diameter suction cups, bubble wrap and blue packing foam, shown in Fig. 8.9. While bubble wrap and packing foam might routinely be employed, the suction cups were studied as a slightly different mechanism to support the structure. Drive point FRFs and input spectra were consistent with earlier results.

The frequencies and damping of the identified modes are summarized in Table 8.5. The identified flexible mode shapes are shown in Fig. 8.10. The flexible modes from prior testing are shown for reference.

Table 8.5 shows little variation in the natural frequencies and modal damping between the suction cups, bubble wrap and foam for the flexible modes. This implies that this boundary condition does not affect the modes of the structure in a significant way which is largely due to the large attached mass. The large attached mass has the effect of simulating a seismic anchor and therefore the boundary condition plays a much smaller role in affecting the frequencies and mode shapes. But overall the suction cups were determined to be the best of the configurations investigated.

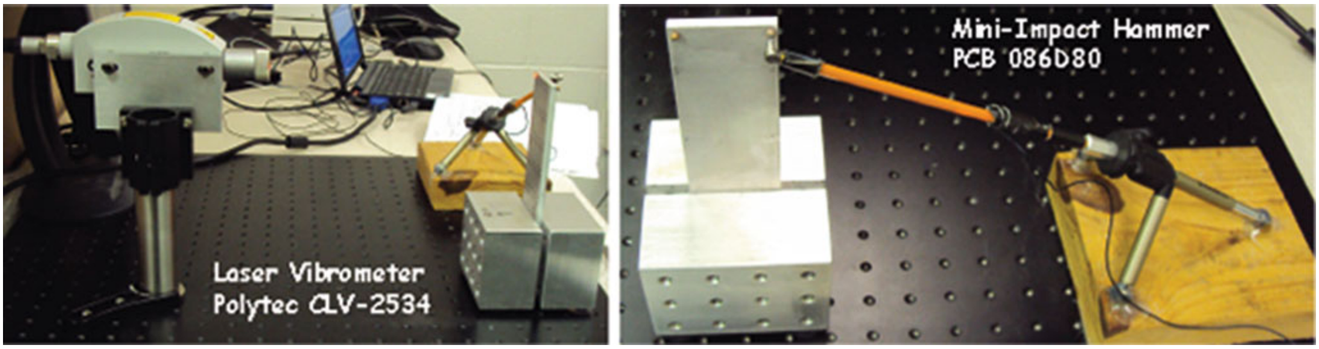

Fig. 8.8 Mini impact hammer and laser setup

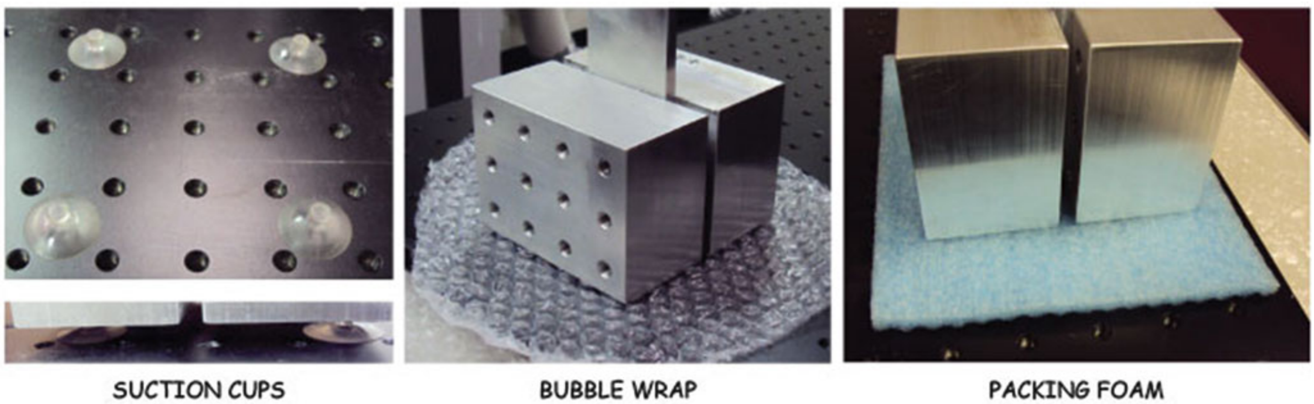

Fig. 8.9 Suction cup, bubble wrap and packing foam used as support padding

Table 8.5 Natural frequencies and modal damping for the upright cantilever plate, by padding type

	Natural frequency (Hz)			Damping		
Mode	Suction cups	Bubble wrap	Foam	Suction cups	Bubble wrap	Foam
1	370.0	371.2	369.5	0.41 %	0.18 %	0.21 %
2	1,565.6	1,565.4	1,565.4	0.02 %	0.02 %	0.02 %
3	1,958.2	1,958.5	1,957.9	0.12 %	0.11 %	0.11 %
4	4,924.3	4,923.6	4,923.7	0.06 %	0.06 %	0.06 %
5	5,344.8	5,343.8	5,344.4	0.16 %	0.14 %	0.15 %
6	9,007.4	9,009.7	9,008.8	0.06 %	0.07 %	0.09 %
7	10,277.0	10,275.6	10,276.1	0.05 %	0.04 %	0.05 %
8	12,793.3	12,791.6	12,792.5	0.06 %	0.06 %	0.06 %
9	13,989.2	13,987.1	13,988.6	0.09 %	0.09 %	0.08 %
10	15,248.2	15,245.8	15,245.4	0.07 %	0.06 %	0.04 %

8.4 Shock Response Plate Fixture with Plunger Supports

Supporting larger, heavier structures can sometimes be more difficult. Expensive air ride systems or other complicated support mechanisms have often been deployed. Before mounting a new shock plate on an air piston system, a modal test was necessary for some preliminary shock calculations. A good support mechanism that was economical, easy to set up, and would provide useful results was needed. After some brainstorming, a very different configuration was used – toilet plungers! The dynamic characterization of the aluminum shock response plate was determined with the plate placed on three plungers and again with the plate placed on six plungers (Fig. 8.11). To prevent interference with the accelerometer, for the six plunger test, the plungers were placed at the edges of the plate. For the three plunger test, the plungers were positioned directly beneath measurement points.

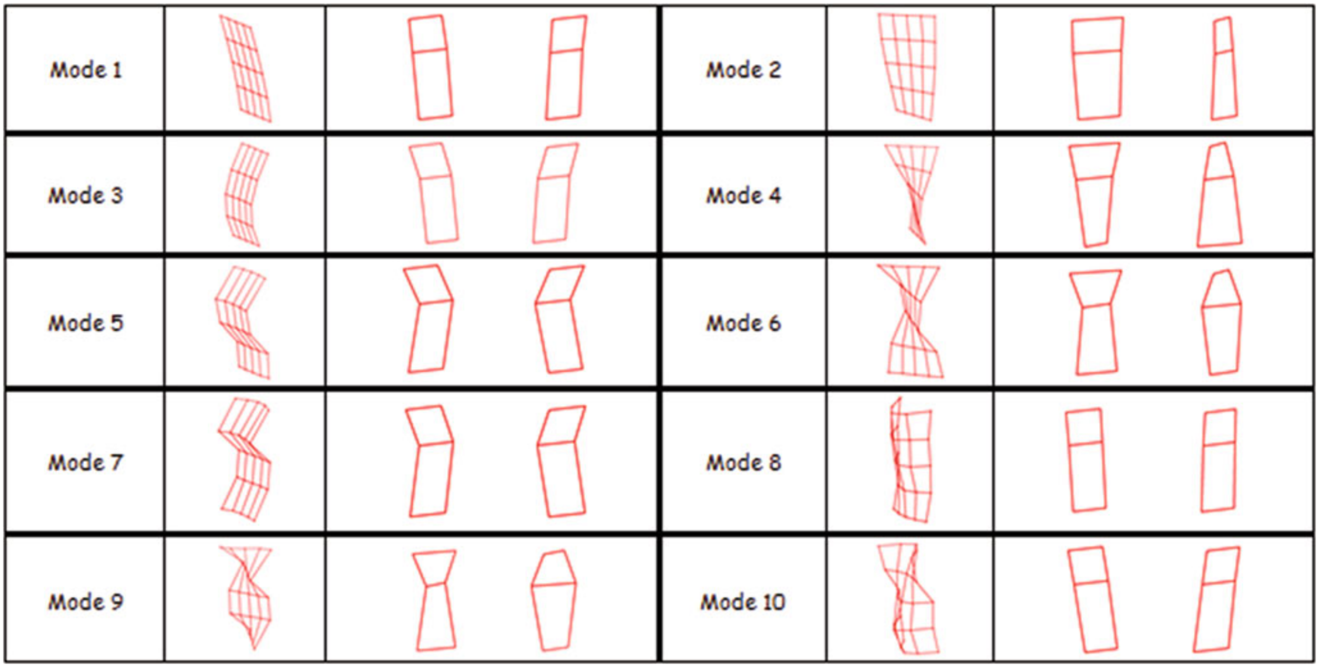

Fig. 8.10 Mode shapes of identified flexible modes, with prior determined flexible modes as reference

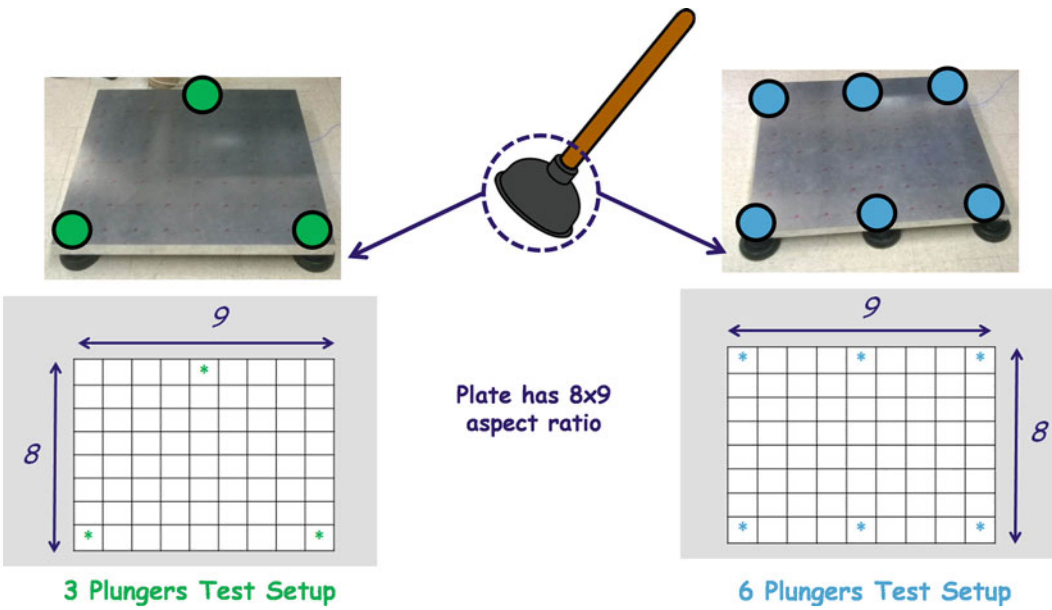

Fig. 8.11 Test setup for three plungers and six plungers tests

For the three plungers test, two plungers were placed at the corners along one of the long sides of the plate and one plunger was placed in the center of the opposite side, as shown in Fig. 8.11. For the six plungers test, three plungers were placed along each of the long sides of the plate as shown in Fig. 8.11.

Measurement points and a coordinate system were defined for both tests. A tri-axial accelerometer was placed on the plate beneath point nine. For the three plunger test, a small sledge hammer with a black plastic tip was used to impact the plate. For the six plunger test, a large sledge hammer with a black plastic tip was used. Measurements were acquired in the X, Y, and Z directions as appropriate. The measurement point locations and testing equipment is shown in Fig. 8.12.

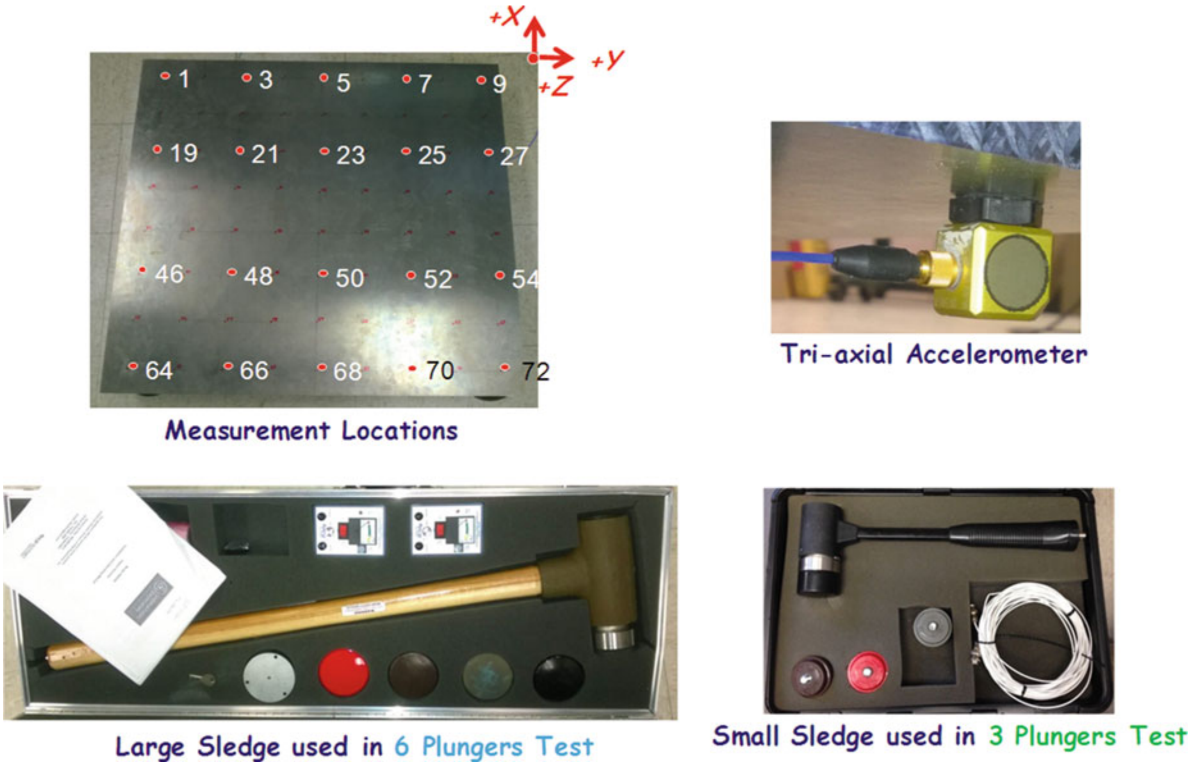

Fig. 8.12 Measurement point locations, coordinate system, and equipment used for three plungers and six plungers tests

Table 8.6 Natural frequencies and damping for three plunger test and six plunger test

	Natural Frequency (Hz)				Damping		
Mode	3 Plungers	MAC	6 Plungers	% Difference	3 Plungers	6 Plungers	% Difference
1	4.167	77.183	4.519	8.10%	6.45	6.39	0.93%
2	4.339	93.340	4.602	5.88%	6.41	6.30	1.73%
3	5.756	91.744	6.816	16.86%	6.81	7.34	7.49%
4	9.013	94.797	9.350	3.67%	5.36	8.21	42.00%
5	10.278	90.015	12.359	18.39%	5.62	10.23	58.17%
6	13.989	91.585	15.967	13.21%	6.16	9.20	39.58%
7	219.399	94.612	217.166	1.02%	0.18	1.36	153.25%
8	315.940	88.481	316.362	0.13%	0.22	0.78	112.00%
9	439.26 3	80.409	439.762	0.11%	0.48	1.20	85.71%

The six rigid body modes and first three flexible modes were evaluated over a bandwidth of 500 Hz using Photon software via LDS Dactron. Data was then processed in LMS. The natural frequencies and damping of the two tests are compared in Table 8.6. The mode shapes from the plunger tests are shown in Fig. 8.13.

Table 8.6 shows that using six plungers rather than three plungers increased the frequencies of the six rigid body modes and the second two flexible modes; decreased the frequency of the first flexible mode; and either increased or decreased the damping depending on the mode. Differences in damping were most noticeable after the first three rigid body modes. Overall, the toilet plungers were seen to be a very good support configuration for the heavy shock plate and provided very good vertical and lateral support (at a cost which is far cheaper than any of the more elaborate air floating systems used).

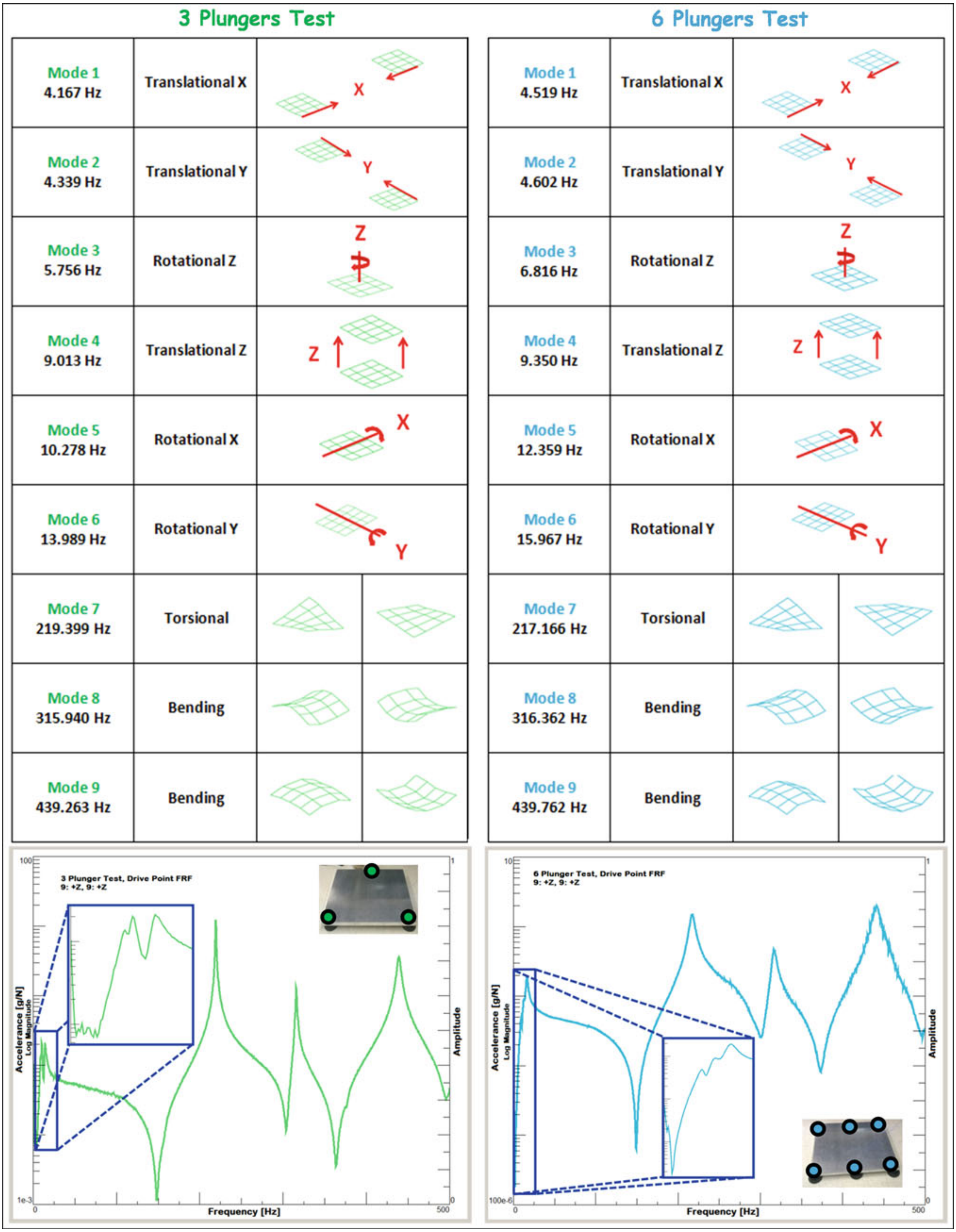

Fig. 8.13 Results of three plungers and six plungers tests

8.5 Conclusion

The test boundary conditions can have an effect on the measured frequencies for an experimental modal test. A few examples were shown to illustrate some non-conventional boundary conditions that could be employed – from marshmallows to plungers. Analysis of the various cases showed that the frequencies might have slight shifting but, more importantly, the organization of the mode shapes might change; this was seen in the organization of the closely spaced bending and torsion modes of one structure. Expensive solutions were not necessary to obtain suitable support scenarios. Care must be exercised when setting up the boundary condition mechanism and variations may need to be considered to assure that proper data is collected to identify the modes of the structure under test.

References

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3. Avitabile P (2010) Will the support mechanism have any effect on FRFs? Does bungie cord vs. fishing line make any difference? SEM Experimental Techniques, Dec 2010