MODAL SPACE - IN OUR OWN LITTLE WORLD by Pete Avitabile

Illustration by Mike Avitabile

So what is the best way to make a free-free test set up … because nothing is really free-free.
Alright … let's discuss some non-traditional ways to do this.

Alright … so many people always ask me what is the right way to set up for a free-free test. Well there is no right way but certainly there can be very poor ways to do this.

The most common way is to use bungie cords (or something similar depending on the weight of the structure). I have seen missiles supported from bungie cords as well as large wind turbine blades. I have seen airbag systems deployed in many different instances. Well, I could go on and on with all the different ways we could do this. But the bottom line is that you have to make sure that the boundary conditions are not intrusive on the system under test. The boundary condition should have little effect on the flexible modes of the system. When this is done, then we can say that the test set up has very little effect on the flexible modes of interest in the test structure.

But we actually need to check that to make sure that the test set up does not have an effect on the flexible modes of the system. We need to set the structure up with one set of support locations and then retest the structure with a different set of support locations or change the stiffness of the support at the support location (possibly by using twice as many bungie cords or changing the pressure in the air bag support system for instance). If the flexible modes of the system do not change appreciably then the support condition likely has little effect. But there might still be some effect from the boundary condition and it needs to be carefully checked.

So as an example, I have two structures that were recently tested and some very non-traditional boundary conditions were used. The first is a smaller lighter weight structure that has some very closely spaced frame bending and torsion modes whereas the second structure is a much heavier anchor plate used for some shock response spectrum testing work.

The support for the first structure was actually inspired from a phone conversation with a close colleague where he had mentioned in class that you could use almost anything for an isolation system. A student asked what extremes could be taken and he quickly, as a funny remark, said "I don't care if you use marshmallows if you want". Well hearing that I decided to test one of our standard lab structures with various sized marshmallows; very small mini-marshmallows and very large jumbo marshmallows were used to perform a modal test for our frame structure in the lab. This particular frame is designed to have the first bending and first torsion mode to be very, very close in frequency to the point of being almost repeated.

So the first test (Test #1) was set up with 4 jumbo marshmallows located at the four mid-section of each leg of the frame which corresponds to the node points for the torsion mode. The second test (Test #2) was set up with 10 mini marshmallows distributed around the frame. These two tests were performed and the first thing that was noticed was that the bending and torsion modes were swapped depending on which of these first two tests were used. So a third test (Test #3) was set up where the jumbo marshmallows were located at the corners of the frame.

The rigid body modes were definitely affected by the arrangement of the marshmallows. But it is important to note that the flexible modes also showed a little frequency difference in each of the different configurations. So the boundary condition does have a little effect on the flexible modes of the system. But more importantly, the sequencing of the bending and torsion modes occurred differently in Test #1 and Test #2. So it is very important to realize that the support condition may have an important effect on the frequencies of the modes as well as the organization of the modes. Notice that Test #2 and Test #3 however, have the same organization of the mode sequencing for these two tests. So not only do we need to be cautious about

the shifting of frequencies, we also need to be concerned about the organization of the modes due to the test set up. Figure 1 shows the results of the first two modes for the three different test set up configurations along with the photo of the structure with marshmallow support and typical drive point measurement for each configuration.

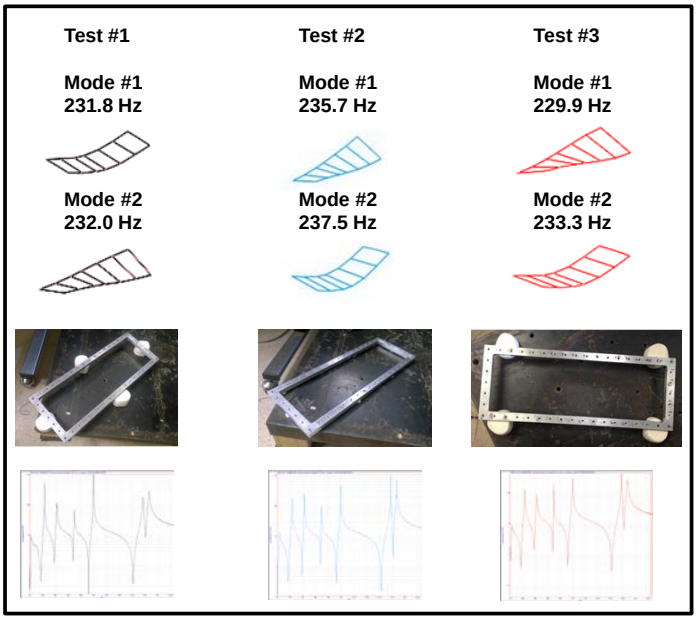

Figure 1: Results of Frame on Marshmallow Support

Now the second structure is a shock response spectrum plate structure that is available in the lab. The structure is mounted up onto an air-piston floatation system. But before the air-piston system was available, a very quick modal test was needed to validate the model and make some preliminary shock predictions. Without the air-pistons to support the plate, a very crude floating support was devised. Now at a university, money is always limited so a pratical, economical support needed to be provided. After some long thought one day, a brilliant idea came upon me. That handy old toilet plunger seemed to be a very good possibility for the support of the shock plate.

The hardware store was quite surprised when I appeared at the cash register with 6 toilet plungers. Our 250lb shock plate was tested with two configurations – one with 3 plungers located at the locations of the air-pistons and one with 6 plungers.

And the results of this test were very good. The rigid body modes in both configurations were very good and the flexible modes were similar as seen in Figure 2 (left) for the three plunger configuration and in Figure 2 (right) for the six plunger configuration. And the results were so good that a recent visit from a European colleague sparked the question where could he buy some of these plungers on E-Bay (to which I replied to just go down to your local hardware store and buy some brand new ones – they really only cost about $5 per plunger and were a bargain compared to some of the more expensive configurations that people have concocted).

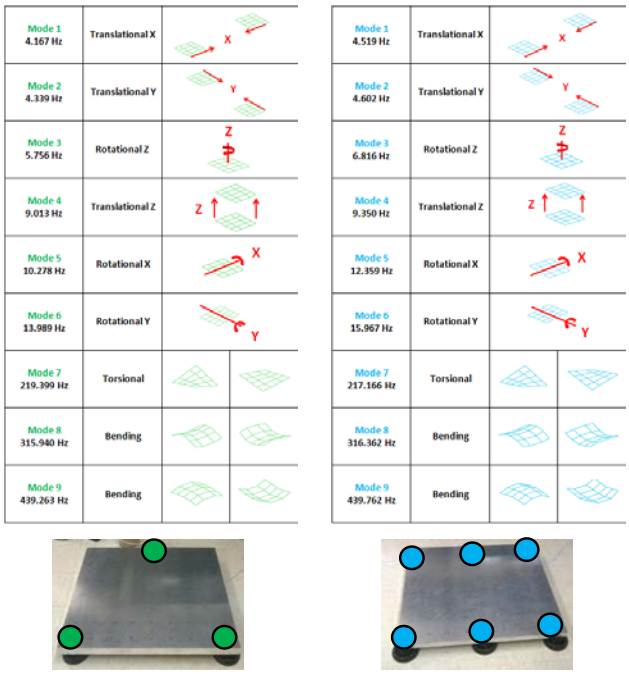

Figure 2: Results of Anchor Shock Plate on Toilet Plungers

So you can see that there can be a number of different and very simple mechanisms to create the free-free test configuration. But you do need to be mindful of the fact that the boundary condition may cause some shifting of the frequency that may be important to the further use of the data for subsequent analyses and that the boundary condition may have an effect on the organization of the different modes of the system as was seen in the first test arrangement for the frame structure.

I hope that this helps to shed some light on the questions you had. You can see that from marshmallows to toilet plungers, many different support conditions can be used to accomplish the support for the system under test – you just need to be careful and check your measurements. If you have any other questions about modal analysis, just ask me.