MODAL SPACE - IN OUR OWN LITTLE WORLD *by Pete Avitabile*

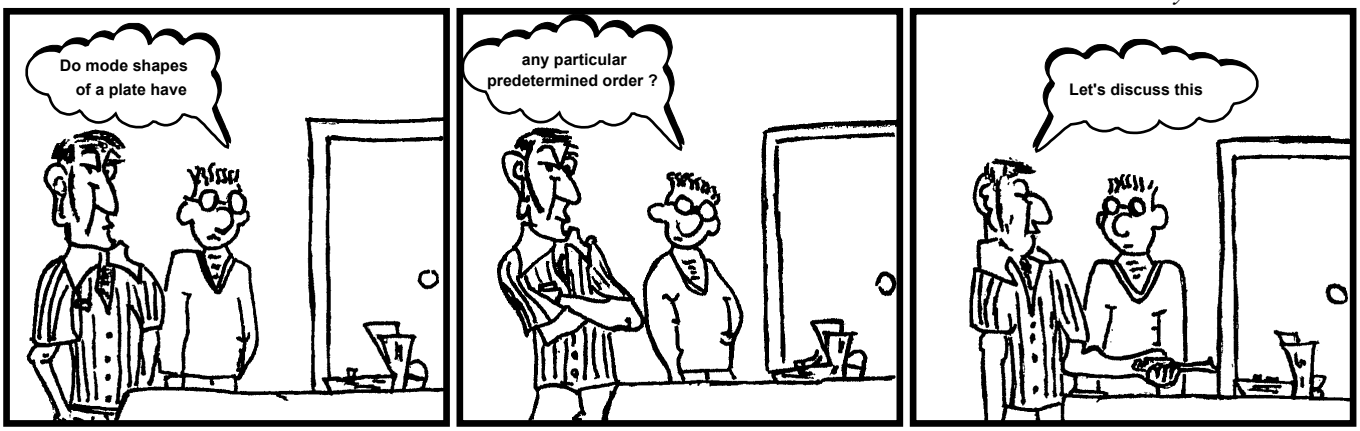

Illustration by Mike Avitabile

Do mode shapes of a plate have any particular predetermined order?
Let's discuss this.

This is a question that comes up more often than you would ever imagine. This needs to be discussed and some examples will be given to explain and clarify this often confused item.

Many times I have heard people say that modes of a structure always first start with torsion. While it may be true for their particular application that the modes that are typically seen in their structural configuration may start with torsion, there is no predetermined rule as to the order or sequencing of modes.

For instance, many people often think that modes of a plate must start with torsion – but there is no mathematical reason for this to occur. It just may have been that all the plate structures that they have seen in the past have had a first mode that was a torsional mode. Of course once someone sees a torsional mode as the first mode of a structure several times, then forevermore, *all plate like structure must have a first mode which is torsion*. ***This is not true at all***.

I remember an instance many years ago when an analysis was performed on a new stiffened body-in-white configuration. The structural engineers had spent a significant amount of time concentrating on designing a structure that had a significant increase in the first flexible modes of the car frame. Prior to that time, the modes of a configuration of this type *always* started first with torsion (T) and then followed by bending (B). When the first analytical models were analyzed, the first mode of the car frame turned out to be bending rather than torsion. There was incredible confusion concerning this since up until this time the first mode was *always* torsion – almost as if it was etched in stone (as the 11th commandment!)

No one believed the model since this appeared to be totally contradictory to what everyone believed to be the "*way things were meant to be*". But there is really no basis for things to be that way. The model is a distribution of mass and stiffness that results in an eigenproblem that yields frequencies and mode shapes which satisfy the force balance equation. If the model is prepared correctly then the solution will identify the frequencies and mode sequence that satisfies the mathematical problem. (Of course, there may have been errors in the model but that's a totally different story.)

The simple fact is that the frequency and mode shape sequence is due to the mass and stiffness distribution of the structural configuration and not due to anything else.

In order to illustrate the mode sequence arrangement possibilities, three different plate configurations with different length to width aspect ratios were generated and finite element solutions were obtained for each. These are shown in the figure with the arrangement from lowest to highest mode from top to bottom. The modes are further indicated with a B for bending along the longer length of the plate, B2 for bending along the shorter length of the plate, and T for torsion about the symmetry axis. For the three different plates analyzed, there is no specific ordering of the mode shape sequence. Each of the plates has a different combination as seen in the figure.

And as long as we are on the subject of mode shapes, the question to ask is if the bending along the longer length of the plate (B) will always occur at a lower frequency than the bending along the shorter length of the plate (B2)? Now before you too quickly just answer that question, stop and think about it for a minute……..

Is this a trick question? What do I need to think about before I answer that question? What are the material properties? And are they the same along the long and short length?

If the material is homogeneous, then the bending mode along the long length (B) will occur before the bending mode along the short length (B2). But what if the material is a reinforced carbon fiber composite where the stiffening fibers run along the longer length of the plate? Then there is a possibility that the plate will be much stiffer along that length. Then it is also possible that the frequency of the bending along the shorter length (B2) may occur before the frequency along the longer length (B).

(Oh my, Toto – I am not sure we are in Kansas anymore!). Obviously, the bottom line here is that you really need to think about this possibility. It is a very possible reality!

I have tried to answer your question about mode order for a plate. Obvoiusly, this holds true for any structural configuration that has characteristic bending and torsion modes – not just a plate configuration. If you have any other questions about modal analysis, just ask me.