MODAL SPACE - IN OUR OWN LITTLE WORLD

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Does gravity come into play when testing to find frequencies? Does orientation make a difference? This is something that needs to be discussed.

There are several different things to discuss in regards to this. There are several different things that may come into play when performing a modal test and we need to talk about this for sure.

Generally, from a theoretical standpoint, the effects of gravity will not have an effect on the frequencies and mode shapes for most of the situations we face. That is because the equations we write for the definition of the system are written about a static equilibrium standpoint and the effects of gravity are not necessarily an influence (but in a moment I will discuss practical situations where this is not necessarily true).

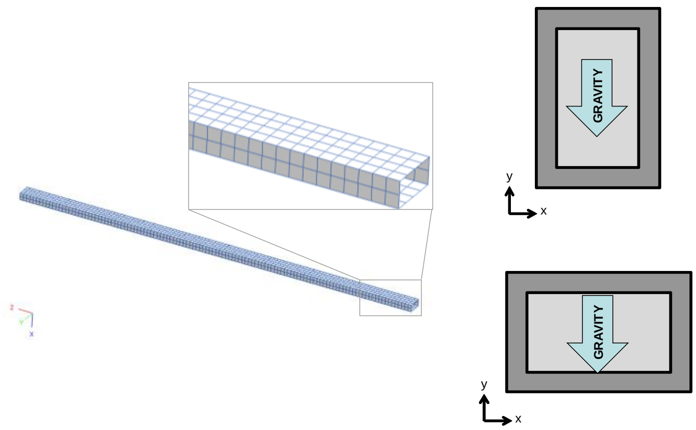

Figure 1: Schematic of Beam for Modal Test

Let's consider a simple beam as shown in Figure 1. Now when we make the finite element model of this beam, it really doesn't matter which way we orient the beam relative to gravity and there generally will not be any difference in the frequencies if we chose the cross section orientation on the top right or the cross section orientation shown on the lower right. The frequencies computed will be the same because gravity is not considered and we are assuming that the structural configuration is evaluated about the static equilibrium point and that *there is essentially no significant deformation of the structure due to the effects of gravity*. (At least that's what we are assuming when we make the finite element model.)

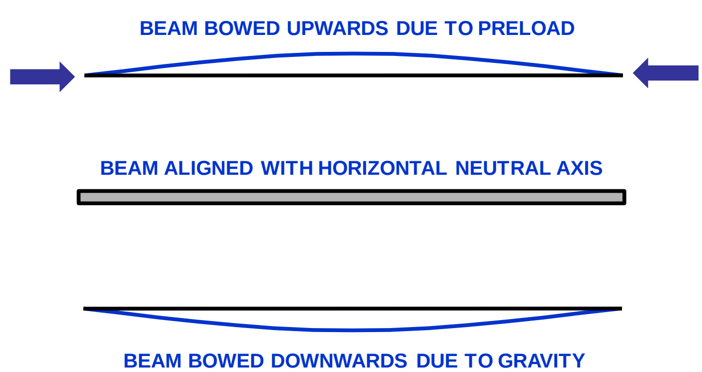

Figure 2: Schematic of Beam in Several Configurations

But it is that last statement that needs some additional considerations. Figure 2 shows several configurations that may need to have some additional discussion. The first configuration is the one shown in the middle section in Figure 2. Here the beam is assumed to be oriented along the neutral axis and there is no significant deflection of the beam. In this case the beam orientation really makes no difference at all. The tested frequencies will not be affected by the orientation of the beam relative to gravity.

But now let's consider the configuration in the upper portion in Figure 2. In this case an axial load has been applied to cause the beam to bow upwards. When this happens then there really is an effect on the stiffness of the beam. The stiffness is increased because of the upward bow of the beam. And we know that this is expected to be true. The arched configuration is actually stiffer than the flat configuration. Just consider any bridge span and the girders are always slightly arched because that is a stiffer configuration. So if a compressive preload is applied and the beam deflects upward, then this arched configuration is slightly stiffer than the nominal undeformed configuration.

So the lower configuration in Figure 2 shows a deformation due to the gravity load. It stands to reason that the deflection due to gravity will have an effect on the stiffness especially for very flimsy lightweight configurations such as wind turbine blades. Now if the beam is rotated and the stiffer cross section is now taking the load due to gravity, then the deflection will be significant lower and the effects of gravity are minimized significantly.

So theoretically, the gravity load does not create an effect because the assumption is that the deflection is small and the gravity effects are insignificant. But if the static deflection is more pronounced due to the flexible nature of the structure then the assumption may not be a reasonable one to make. Then the orientation of the beam can have a significant effect.

So when might this become a concern. Well, for large wind turbine blades, the structure is very flexible and the orientation of the blade cross section (flap vs edge) can have a significant effect on the effective stiffness of the blade due to the orientation of the blade with respect to gravity.

So Figure 3 shows two wind turbine blade configurations and both are sensitive to the orientation of the blade with respect to gravity. The turbine blade is strongly affected by the orientation with regards to gravity and the natural frequencies will be affected by the orientation. Looking at the blade it is very obvious that there is a difference in the two orientations. The flap (weaker axis) direction is much more sensitive to the effects of dead weight than the much stiffer edge direction.

But there is another consideration that many often overlook. The dead weight loading causes a deflection in the structure as expected. But that dead weight deflection may cause some significant loads on some of the internal members – these loads may cause enough deflection in the spars and ribstiffening internal structures that they are deflected into a configuration that is much different than the nominal dimensions on the design drawings. These deflections will basically cause the internal stiffening members to have a much different stiffness that that of the nominal dimensions based on the design drawing dimensions. This is very similar to the preloaded beam shown in the upper portion of Figure 2 which is much different than the nominal dimensions.

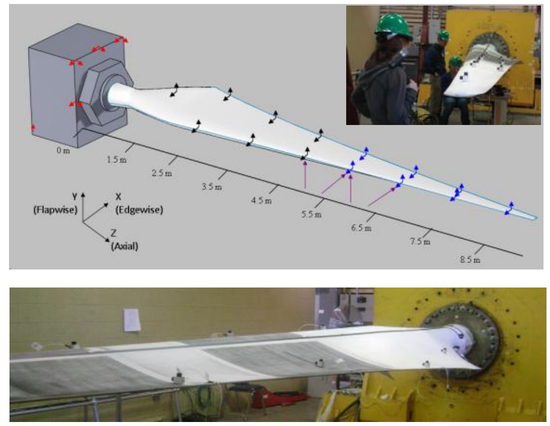

Figure 3: Schematic for 9 Meter Wind Turbine Blade Test

The ribstiffened airfoil panel configuration in Figure 4 is a very good example of a cross section where this may be of concern; the sketch on the right shows a simple wing configuration where the left wing (blue) has essentially no deformation due to gravity but the right wing (red) shows significant deflection due to gravity. For this thin, flimsy panel configuration (red), the dead weight or structural loading can cause deflections which may warp the rib stiffened interior structural panels – and this loading may cause significant deflection to result in a geometry that is no longer following the nominal dimensions identified on the CAD drawings. Therefore the stiffness of these internal ribstiffening members may be very sensitive to the orientation of the test structure when considering gravity loading.

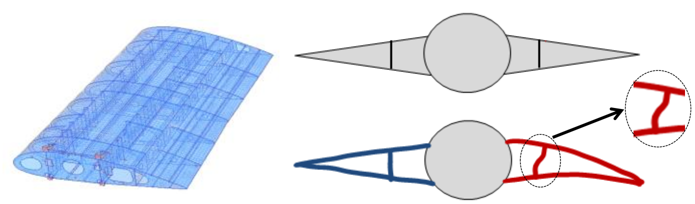

Figure 4: Ribstiffened Panel Airfoil Configuration

So usually we don't have to consider the effects of gravity unless these effects cause significant deflections and seriously change the geometry defining the finite element model.

I hope that this helps to explain the questions you had. If you have any other questions about modal analysis, just ask me.