So now we get to put all the pieces together. So we've looked at different elements of buildings. We've looked at beams and columns and trusses-- lots of different elements, but we need to put them together and look at structures overall.

So we've looked at bridges a little bit, so we looked at truss bridges and cable-stayed bridges. Those tend to have just single elements in them, so it's easier to look at those earlier. But now as we look at buildings, we're going to start beams and columns and trusses. Buildings take all those pieces and put them together, so designing a building or understanding and analyzing a building is just about really combining those elements.

So first thing an engineer would probably do is look at the independent elements. So they first consider the different types of loads that the building's going to be subjected to. Vertical loads are some of the main roads and one of the first things an engineer would look at. So vertical load will come from the self-weight, is what we refer to it as, but the materials themselves. So the building is made of concrete or steel or some other material, but that has a certain weight. And that vertical load from that weight has to get down to the ground.

We also get applied loads from people, furniture, everything that's in the building. All the equipment, whatever materials are in the building. Those, again, are all vertical loads. In addition, on the outside of the building we get snow, which is a big vertical load. Rain can sometimes pool up on the roof.

And those are things we'll look at. So those are vertical loads. So as we analyze and design for those vertical loads, it would be a lot like we did when we looked at beams and columns. So we'd figure out first the load path. So those vertical loads would be either on the roof or on the floor levels. So where the people are generating the loads.

Those would be applied directly to the beams. So those beams-- we'd look at the beams. Those beams we have analyzed to make sure they're OK, then those beams would carry the loads up to the columns. And the columns of carry the loads on the ground. And we would call that a vertical load flow trying to figure out where the load starts and how it gets down to the ground in a safe manner.

So beams-- if we're looking just at the beam element-- an engineer would just go back to beam design that we talked about. So a beam could fail in bending or it could fail in shear-- those are the two main ways. So a longer, slender beam would fail in bending. Or just reach too much bending. Too much tension or compression. And then if it's a shorter, deeper beam, it would fail probably in shear.

So an engineer would look at that, make sure the beams are OK. Then move on to the columns. Then check to make sure the columns are OK. They could fail in compression or in buckling, so they'll analyze and make sure that was OK.

So that's load the vertical load flow. So as the loads, we find where they're generated. We figure out how to get them to the ground. We also have to deal with lateral loads or horizontal loads, and the two main horizontal loads that we deal with in buildings are wind and earthquake. So wind pushing on the side of the building.

Earthquakes are little different. They generate a motion on the ground, but that actually generates a lateral force as well. So how do we deal with these horizontal loads to a building and what will they do to a building? So a wind load is probably easier to begin with to just imagine a wind load. The wind load on the side of the building will apply forces to the side and cause the building really just to bend like a beam.

So we saw that a little bit with the Eiffel Tower. So we analyze the Eiffel Tower for a wind load, and then we talked about beams. And that Eiffel Tower behaved just like a beam. So if you turn your head, you have a cantilever beam.

And most buildings, we can actually do a first pass analysis for wind or earthquake loads by modeling them as beams. So instead of tension compression being within a single member as it would be with a beam, we'll have tension compression and different columns in that scenario by modeling a building as opposed to a single element but the concepts will be the same. So a shorter, wider building will tend to fail in shear, whereas a tall, more slender building will tend to bend more. So it'll have more of a bending behavior.

And then we'll look at where tension compression is due to that bending. We'll look at those columns. See if those columns can take that extra compression. See if they can handle the tension.

The other two failure modes for an overall building overturning and sliding. So a building just toppling over or a building sliding along the base. These are really just a function of the connections at the base.

So making sure we have strong enough connections to withstand overturning, to withstand any type of lateral sliding.

So we're going to build some simplified models of the buildings, and engineers often do build simplified models. There's a lot of data. If you're looking at a big three dimensional model and trying to figure out what's happening, you can get buried in all the numbers.

So coming up with a simplified model is very helpful. So we can take a standard three-dimensional model of a structure. And what I'll usually do as a first pass is come up with a two-dimensional model. So collapse everything to two dimensions. And most buildings are pretty repetitive, so that's a fairly effective way to make it simpler.

So collapsing it into a two-dimensional model means I'm going to take all the columns and just model the columns in the beams all along a two-dimensional plane. I can further make an even simpler model, which is referred to as a one-dimensional model by collapsing all those columns together and all the mass on the floor levels together. And so all the columns get grouped along one line, so that's where we get one-dimensional model.

Everything's on one line, and then at every floor level, we lump the mass. Does a really good job of actually predicting dynamic response, and lumping all the mass of the floor level is actually a good way to do it since that's where most of the mass typically is. That's where the beams are. That's where the people are, all the equipment are.

So if you have a one-dimensional model for a building with multiple floors, it would be referred to as a multi-degree of freedom system. What I have here are single-degree of freedom system models. So these would represent the same thing. It's a one-dimensional model. Everything's collapsed along a single line, but it's for a one-story structure. So it's just one story tall.

I have two different versions to represent a taller building and a shorter building, and that's one of the things I want us to experiment with is do they behave the same? Do they behave differently? So I tried to make them with very similar masses, but they have different heights.

The different heights of the columns represent the stiffness. The stiffness again was how much is going to displace for a given force. So if I apply the same force to both of these ones, one is going to displace more than the other. So this one displaces more.

The shorter one would be referred to as the stiffer system as opposed to the taller one, which would not be quite as stiff. Hopefully you have a dowel or something you can use to build a single-degree of freedom system model or one of these lollipop models. It's just a wooden dowel in my case. We could also use a twig-- anything long and slender-- and a lump of clay on top.

And what you want to do is experiment with how it tends to want to behave. So as I pull it back and release it, how does it want to oscillate? And will it oscillate different if it's got a different height or different stiffness? How about if I took all this mass and put it on a single lump? Would that make any difference?

So you're trying to experiment with heights of column and amount of mass and figure out how the building wants to respond. If you don't have materials to build a physical model, go ahead and use the online simulator to experiment with different masses and stiffnesses of columns virtually.